MACROECONOMIC INFLUENCES ON TROPICAL FOREST DEPLETION: A CROSS-COUNTRY ANALYSIS, 1967-1985

By

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The research examined the influence of global economic fluctuations on the depletion of tropical forests from 1967 to 1985. Data from 45 tropical developing countries were used to: (1) establish the relationship between global economic conditions and tropical forest depletion; (2) determine whether forest depletion varied by geographic region, income group and state of international indebtedness; and (3) estimate the influence of population, income, prices, debt service, food sufficiency and arable land availability on tropical forest depletion.

Faustmann's model provided the framework for analyzing governments' forestland allocation decisions in the context of a changing global economy.

The area of closed broadleaved forests industrially logged was used as indicator of forest degradation (qualitative depletion). It correlated highly with available data on deforestation (quantitative depletion).

Four subperiods were defined. Period 1 (1967-71) were years of fixed currency exchange rates. Period 2 (1972-75) saw grain shortages, the first oil crisis, and increased lending to developing countries. Period 3 (1976-80) featured conditional lending and the second oil crisis. Period 4 (1981-85) was marked by severe recession and the debt crisis. Econometric estimates and calculated elasticities indicate that macroeconomic factors greatly influenced forest depletion during the study period. While logging-related forest degradation did not vary by region, income group and credit status, deforestation was significantly greater in highly indebted countries during 1976-80, the period for which deforestation data were available.

During the fixed exchange years, forest depletion was linked to the export value of tropical wood. In the 1970s, increased demand made possible by rising per capita income and the drive towards greater food self-sufficiency encouraged forest depletion.

Higher debt service was not incompatible with forest preservation while credit was available. However, real currency devaluations were associated with significant forest destruction starting the late 1970s. Furthermore, lower export value of tropical wood encouraged deforestation

as countries compensated by increasing volume of wood extracted. Foreign exchange difficulties and greater reliance on agriculture in the 1980s contributed to forest depletion.

CHAPTER 1
INTRODUCTION

The large scale depletion of the world's tropical[1] forests is a serious environmental problem with significant economic consequences. Species extinction leading to decreased biodiversity, soil erosion leading to siltation and flooding, microclimate as well as global climate changes have all been linked to large scale forest removal.[2] These ecological changes translate into real economic costs in terms of lost lives, property and productivity in affected areas worldwide.

In the Indian subcontinent, for example, deforestation and consequent hydrological changes tripled the area subject to annual flooding from 19 million hectares in 1960 to 59 million hectares in 1984 (Brown and Young, 1990). This has affected food production and the subcontinent's ability to feed its people.

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[1] The tropics lie between the Tropic of Cancer and the Tropic of Capricorn situated at 23.5^0 latitude north and south of the equator.

[2] For a review of the evidence, see Fernow (1977), Sutlive et al. (1981a), World Resources Institute (1985), US Interagency Task Force on Tropical Forests (1980), Myers (1980, 1984), Prance (1986), Jordan (1987).

Where communities depend on the forest for energy[3] and other needs, shrinking forests translates into greater time and effort, usually of women and children, spent collecting increasingly scarce forest products. To the extent that time is taken away from agricultural production, forest depletion can adversely affect agricultural output. The reallocation of women's labor away from home production and food preparation to fuelwood collection has also been linked to deterioration in the quality of rural health and nutrition (Bajracharya, 1983; Kumar and Hotchkiss, 1988).

Soil erosion from deforested watersheds threaten public investments, usually of borrowed funds, in multi-purpose dams and irrigation facilites. Rapid siltation is drastically reducing productivity and economic life of many such infrastructures. Depletion of tropical forests implies significant loss of economic potential.

Tropical forests are the planet's most complex and species-diverse ecosystems. They are very valuable sources of genetic information. In 1980, they were estimated to cover only 7% of the Earth's land surface, yet they contained 40% of the planet's 5-10 million species (Longman and Jenik, 1974; Myers, 1984). Many potentially commercially valuable species perish with the forest, taking with them information acquired from millions of years of evolution.

---

[3] Fuelwood, mostly collected from open forests and woodlands, provide 63% of the total energy consumption in developing African countries, 17% in Asia and 16% in Latin America. In some countries, the share of fuelwood out of total energy consumption may be greater than 90% (FAO, 1985b). Also see Earl (1975).

Tropical forests also represent one of the Earth's main stocks of stored carbon. It is estimated that a hectare of forest absorbs 5.5 tons of carbon, a "greenhouse" gas, from the atmosphere annually (Flavin, 1990). This absorptive capacity is lost with deforestation.

Definitions

To avoid confusion,[4] the terms "depletion" and "deforestation" need clarification. There are different degrees of forest depletion depending on extent of removal of tree cover. Forest depletion can be classified as being either qualitative or quantitative.

Qualitative depletion or degradation involves impoverishment of the forest through marginal or pronounced disturbance without complete removal of forest cover. Selective logging of commercially valuable wood species is an example of an activity resulting in qualitative forest depletion. Although there is no reduction in size of the forested area, forests are degraded and, in many cases, their survival seriously compromised after logging operations.

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[4] Much of the controversy during the past decade about the supposed discrepancies among different estimates of tropical deforestation has resulted from differences in the types of forests considered and in the operational definition of deforestation. See Melillo et al. (1985).

Quantitative depletion or deforestation, on the other hand, involves the complete and permanent removal of all forest cover. Deforestation occurs when forests are cleared for slash and burn cultivation, pasture or export crop production.

Typically, deforestation occurs in steps. Logging and such disturbances as mining and road building on forested lands often eventually lead to complete removal of forest cover. Thus, the distinction between forest degradation and deforestation is usually artificial, separated only by time. This is particularly true where great demand for land prevents forest regeneration following logging and other extractive activities.

Tropical Forest Depletion: The Process

Early estimates of the area of tropical forests destroyed each year ranged from 2392 to 6050 million hectares (Sutlive et al., 1981b; Kartawinata et al., 1981; Lanly, 1982; Myers, 1980, 1984, 1986). The average annual rate of tropical deforestation was estimated to range from 1% to 2% with some countries, such as the Cote d'Ivoire, experiencing deforestation rate as high as 6% per year (Myers, 1984). In 1980, it was projected that forests in developing countries would decline by an average of 3% to 6% per year in some cases, faster in others (Barney, 1980).

Recent data from satellite imagery show that deforestation in the tropics is a more serious problem than it was thought to be. Actual deforestation in Brazil and in India in 1980, for example, were respectively 3 and 10 times the early estimates (Repetto, 1990).

Commercial logging is often the first step on the road to deforestation. Walker (1987, 1990) theoretically analyzed the two-step process from logging to deforestation. Allen and Barnes (1985) found that deforestation in 28 countries over the period 1968-78 was linked to intensity of wood harvesting.

On average, only 5 to 35 cubic meters of merchantable wood are extracted per hectare of tropical forests. These small commercial volumes, however, have been associated with disproportionate damage to the forest due to careless use of equipment and inefficient logging practices.

For every cubic meter of commercial timber extracted, almost two cubic meters of wood are damaged or destroyed. Typically, at least half of the remaining stock, including immature trees of commercial value and harvestable stocks of less desirable varieties are damaged beyond recovery (FAO, 1974; World Bank, 1987a; Jacobs, 1988; Repetto, 1990).

In addition, logging adversely affects soil quality and, therefore, future timber harvests.[5]

Logging also threatens the culture and survival of communities dependent on the forest for subsistence (Davis, 1977; Myers, 1980; Hecht, 1985; Scott, 1988; Sloan and Paddoch, 1988). It leaves behind access roads and trails that make logged-over forests vulnerable to permanent colonization and settlement by landless peasants, ranchers and speculators.

The demands of a growing population for food, fuel and housing coupled with institutions[6] that provide unequal access to income and existing arable lands have encouraged forest clearing in many developing countries. As land rents increase with demand[7], the poorest and least productive agricultural producers are pushed into the forest frontier by their inability to successfully compete for cultivable lands. Logging roads serve as major arteries leading would-be settlers and cultivators into the forest.

Cultivation of forest lands per se is not the problem. Forest lands have been sustainably cultivated by indigenous groups of shifting cultivators for centuries (Clay, 1988). Traditional practice involved clearing a small patch of forest, burning the slash and cropping the area for 2-3 seasons.

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[5] Routledge (1987) developed a dynamic programming algorithm to assess the direct long term losses associated with destructive logging practices.

[6] In many countries, the colonial experience destroyed indigenous institutions that promoted forest and natural resource conservation. See Bromley (1989b).

[7] Refer to Ghatak and Ingersent (1984) for a theoretical discussion of land rent.

Burning rids the land of unwanted vegetation with minimal human energy expenditure, releases organic materials from the slash, and makes the land more suitable for crop and animal production (Nye and Greenland, 1960). In the process, however, it releases carbon into the atmosphere, contributing to global warming. Carbon emissions from tropical deforestation is estimated to be at least 1.66 billion tons annually (Table 1-1).

Table 1-1. Estimated carbon emission from deforestation in selected tropical countries.

Country	Carbon Emission (million tons)
Brazil	336.00
Indonesia	192.00
Columbia	123.00
Cote d'Ivoire	101.00
Thailand	95.00
Laos	85.00
Nigeria	60.00
Philippines	57.00
Burma	51.00
Malaysia	50.00
65 Other Countries	509.00
TOTAL	1659.00

Source: Flavin, C. (1990). Table 2-2, p.21.

After several cropping seasons, declining soil fertility and weed invasion make it necessary for the forest clearing to be fallowed and for a new one to be made. Traditionally, the fields were fallowed for 7 to 25 years allowing them to regenerate into secondary forests before they are again brought back into the production cycle (Conklin, 1957; Geertz, 1963; Clark and Haswell, 1966; Janzen, 1973; Sanchez, 1976).

This system of rotational fallows and shifting fields, when practiced at appropriate levels of population density, causes little lasting damage to forest productivity. It also gives reliable yields with minimum susceptibility to pest outbreaks (Rambo, 1980).

In recent decades, however, increased demand for forest lands have led to shorter fallow periods which do not allow for forest regrowth. Traditional shifting cultivators have been joined by peasant communities driven to the forest by landlessness, speculation, and absence of employment opportunities elsewhere. Large farmers and corporations also came lured by price and land tenure incentives, clearing vast tracts of forests for cattle and plantations of export crops (Myers, 1984; Hecht, 1985; Bunker, 1985; Repetto, 1987; Mahar, 1989).

These recent arrivals, possessing little cultural adaptation to forest environments, adopt agricultural practices that leave little prospect for forest and soil regeneration. As a result, forests have been irreversibly lost and soil fertility mined beyond recovery.

The fragility of tropical forest soils and their general unsuitability for agriculture have been manifested in rapid soil nutrient depletion, erosion, productivity decline, and lower agricultural returns[8] (Lal et al., 1986; Sanchez, 1976). Labor surpluses exacerbate the situation by pushing marginal productivity even lower. In order to maintain output level, additional areas of forest often have to be cleared.

Government Policy and Tropical Forest Depletion

Ever since Malthus, population has occupied center stage in discussions of natural resource depletion. While the role of population continues to be recognized in the case of tropical forest depletion, it is increasingly argued that institutional factors and economic conditions, both domestic and international, have just as much, if not more, influence on the fate of tropical forests. There is growing consensus among analysts that logging and forest conversion to agriculture have resulted largely from government policies.[9]

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[8] Ehui and Hertel (1989) analyzed the relationship between deforestation and agricultural productivity in Cote d'Ivoire.

[9] Land use changes due to individuals' response to government policy can be examined analytically using a model similar to one discussed by Stavins and Jaffe (1990). For specific cases of government policy affecting forest use, see Mahar (1989),

About 90% of all tropical forests are public forests under government control and protection (FAO/UNEP, 1981). Governments derive revenues from logging and other economic activities on public forests through user fees, royalties and taxes. Hence, they stand to benefit from some degree of forest exploitation or conversion to more profitable types of land use.

Unfortunately, although not surprisingly, governments have generally failed to effectively manage and protect public forests. Commercial logging which typically leads to deforestation have had either express or tacit government approval.[10] In many countries, the major logging concessionaires are state-owned or state-controlled corporations with substantial foreign capitalization. With very few exceptions, governments have allowed the major portion of forest resource rents to flow to timber concessionaires, speculators, and their foreign partners. Bureaucratic corruption has been blamed for this substantial loss of revenues from forest resources (Repetto, 1990; Porter, 1988; Payer, 1982).

Southgate (1988), Repetto (1986, 1987, 1990), French (1986), Salati and Vose (1983), Smil (1983), Southgate et al. (1984), Gradwohl and Greenberg (1988), Bromley (1989a), Blaikie (1985), and Hecht (1985).

[10] The failure of governments to protect public forests from illegal logging and encroachment can be viewed as constituting tacit consent.

Many governments tended to view forests as obstacles to development. Using land tenure and other incentives, they have directly or indirectly encouraged forest clearing for agricultural production, notably, of exportable crops (Guess, 1981; Blair and Olpadwala, 1988). Unfortunately, government-supported production activities on cleared forestlands have generally proven to be not only environmentally disastrous but also economically nonviable. Forest clearing for cattle ranching in Latin America readily comes to mind (Hecht, 1985; Myers, 1980, 1984; Fearnside, 1987; Mahar, 1989; Mendes, 1989; Pearce et al., 1990; Pearson, et al., 1990).

Where strong political interests conspire against the implementation of land reform, governments have justified forest colonization and resettlement programs as means of achieving a better balance between population and land resources while, at the same time, addressing distributional concerns[11].

Government policies, however, are not created in a vacuum. Although governments must ultimately bear responsibility for their policies, the constraints imposed by global economic conditions and the pressures exerted by international development agencies have had important influence in shaping government policies. Dramatic changes in the world economy, including the oil crises of the 1970s and the debt crisis of the 1980s, highlighted the importance of external factors constraining government policy-making and inducing resource depletion.

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[11] Among 122 developing countries, 116 have, at one point or another, implemented population redistribution programs. See Shrestha (1987).

Indeed, for most tropical developing countries, conditions in the international market appear to have provided much of the impetus for forest exploitation. Many countries, particularly those in Southeast Asia, have relied on foreign exchange earnings from their forest products exports[12]. Other countries have encouraged agricultural cultivation on forestlands as a means of generating foreign exchange through exports or of saving foreign exchange through import substitution.

While the number of studies on tropical forest depletion has increased in recent years, there remains a gap in knowledge about the economic factors at the aggregate level driving the depletion process. There have been very few cross-country statistical studies examining the role of economic factors in the depletion of tropical forests (See Allen and Barnes, 1985; Rudel, 1989). This study was an attempt to fill the gap.

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[12] Despite their significant foreign exchange contribution, however, wood exports represent only 2% of total wood extracted from tropical forests. About 50% of the wood is burned or left on the site, 43% is used for fuelwood and 5% for domestic timber. See Breunig (1987).

Objectives

In broad terms, the research aimed to contribute towards understanding the relationship between macroeconomic conditions and forest depletion in tropical developing countries. The specific objectives of the research were as follows:

(1) to establish the relationship between global economic conditions and tropical forest depletion;

(2) to determine if the magnitude of forest depletion varied by geographic region, income group and international indebtedness;

(3) to estimate the impact of selected macroeconomic variables on tropical forest depletion.

This research expected to provide much needed information and insights on the nature and extent of influence of macroeconomic factors on the forest resource base in developing countries. The results of this study will be of use and interest to all concerned about development and the state of the world's environment. The insights gained from this investigation will be particularly useful to policy makers, environmental action groups, and international institutions involved in the design of policies affecting forest resource use in developing economies.

Analytical Framework

By examining tropical forest depletion in the context of a changing global economic environment, this study adopted the systems perspective advocated by Odum (1983). This perspective maintains that in a nested, hierarchical set of systems, a unit within the set responds to fluctuations in the larger system above it in the hierarchy and, at the same time, affects the larger system by its own fluctuations.

However, while fluctuations in the larger system percolate all the way down to the smaller systems, fluctuations in the smaller systems are less readily felt by larger systems higher up in the heirarchy. According to this perspective, in order to understand the behavior of any given system, it is essential to broaden the boundary of analysis to include the larger system from which the major fluctuations originate.

This study considered the following nested systems: (a) the forest resource system; (b) the national economic system of developing countries with their people, government and natural resource endowments; and (c) the world economic system.

Forest depletion was seen as a perturbation observed at the level of the forest resource system, manifested as qualitative deterioration or quantitative reduction of the forest resource base. While the characteristics of the forest resource base determine its vulnerability to stresses, the major roots of forest depletion were believed to lie outside the forest system itself. The fluctuation in the macroeconomic system was hypothesized to be a major factor explaining forest depletion in tropical countries.

Within the boundary of the national economic system, the government was considered to be of major importance in the allocation and disposition of forest resources. As discussed in earlier sections, over 90% of tropical forests are under government jurisdiction.

Government resource allocation decisions and policies respond and are sensitive to the dictates of global market realitites, the institutional context within which the national economic system is embedded. This is especially true of small and open developing economies, minor players in the global economic system, whose fortunes rise and fall with the world markets.

Data limitations precluded detailed modeling of the interrelationships among the global economy, national economy and the forest resource base. However, available data allowed the conditions at the level of the global economy to be described along with those of the national economy. The data also allowed the calculation of indicators of forest depletion hypothesized to have resulted from changing aggregate economic conditions.

While the suspected economic causes and the resulting forest depletion were observable (even if, in some cases, only indirectly), the mechanism linking the two together was not observable. The operative invisible mechanism could only be conceived in the abstract with the aid of economic theory.

The government, in its capacity as forest manager, was believed to be the key element in the invisible mechanism. Why a government would allow its country's forest resources to be depleted by commercial exploitation and conversion to alternative land uses was explored in a cost-benefit context. The factors that affect a government's cost-benefit calculus were examined conceptually. However, no attempt was made to explicitly estimate and test an empirical model of government forest allocation behavior.

Instead, a "dose-response" relationship between macroeconomic conditions and forest depletion was hypothesized. Reduced form specifications linking forest depletion with aggregate economic conditions were estimated. Forest depletion, as measured by appropriate indicators, was expressed as a function of macroeconomic and demographic variables. Essentially, the macroeconomic variables were summary descriptors of the conditions at the interface between the global and the national economic systems.

Data from 45 tropical developing countries averaged over four subperiods of the years 1967 to 1985 were used in the statistical regressions. The 19-year span covered by the study were characterized by major changes in the world economy and by massive destruction of tropical forests.

Although statistically significant regression results do not establish causality, they provide evidence of the existence of a relationship between forest depletion and the significant explanatory variables. Elasticities calculated from estimated regression coefficients were interpreted as indicators of the impact of significant variables on the forest resource base.

If perturbations at the aggregate level had nothing to do with tropical forest depletion, the coefficients and elasticities of the macroeconomic variables would have been statistically equal to zero. Since their coefficients and elasticities were statistically non-zero, it was concluded that macroeconomic factors did influence the extent of forest depletion. Which macroeconomic variables and how they relate to forest depletion are discussed in the following chapters.

Overview of the Dissertation

This dissertation has five other chapters. Chapter two describes the global context of tropical forest depletion during the study period. It reviews important developments in the world economy and discusses their effects on developing countries' forest resources.

Chapter three examines the economics behind a developing country's government's decision to allow logging and forestland conversion to agriculture.

Chapter four describes the data used in the study and the variables included in the statistical models. It explores the nature of the variables' relationship to forest depletion.

Chapter five discusses the statistical models estimated, the procedures used to test various hypotheses, and, presents the test results. It also interprets the elasticities calculated from the regression coefficients.

Chapter six closes the dissertation with some comments on the implications of the findings of the study for forest conservation and development planning in the world's tropical regions.

CHAPTER 2
THE GLOBAL ECONOMIC CONTEXT, 1967-1985

The close of the second world war saw the birth of newly politically independent countries, most of them in the tropical regions. They were set on their course towards "development"[1] with some measure of aid from their former colonialists which were (and, for the most part, still are) their major trading partners. History consigned these countries to be engaged in an unequal partnership in which developing countries were clearly the junior partners. Decades later, the nature of the relationship had not substantially changed.

Developed countries have had important influence in policy-making in the developing world. Two powerful institutions--the International Monetary Fund (IMF) and International Bank for Reconstruction and Development, more popularly known as the World Bank--have been very instrumental in advancing the interests of industrialized countries in developing regions. The policies laid down by these institutions have had profound impact on the conditions of the macroeconomy and the context of natural resource use in developing countries.

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[1] The term "development" tended to be very narrowly defined as industrialization.

The IMF and World Bank

The IMF was created out of the Bretton Woods conference in 1944 which saw the need for an international organization responsible for maintaining exchange rate stability, freedom from exchange restrictions and convertibilty of currencies. The IMF was to set the tone for worldwide monetary policy. It was to restore order to the international monetary system shattered by the Great Depression and the second world war, to prevent competitive devaluations, and to work towards the expansion of international trade and investment. These were thought to be necessary for the attainment of economic development and full employment in member countries.

The World Bank was established by the same conference to supplement the IMF's functions and to provide member countries funds for long term investment. World Bank financing has been primarily from resources obtained by borrowing from the international credit market. Borrowers are charged interest rates sufficient to cover the Bank's borrowing cost and operating expenses (Van de Laar, 1980; Payer, 1982; Goode, 1985; Le Preste, 1989). The policies of the World Bank reflect those of the IMF.

Collapse of the Bretton Woods System

The period from 1967 to 1971 witnessed the collapse of two important pillars of the IMF--the system of agreed par values and the gold convertibility of the US dollar. These happened with the Nov. 1967 devaluation of the pound sterling and the Aug. 15, 1971 suspension of the US dollar's gold convertibility (De Vries, 1986). The Nixon administration's decision to suspend the dollar's gold convertibility, in the face of what then seemed to be intolerable current account deficits, effectively ended the system of fixed exchange rates established by the Bretton Woods Conference in 1944. Currency adjustments worldwide after the collapse of the system of fixed exchange rates ushered in an era of greater volatility in international prices.

Grain Shortages

In 1971, 1972 and 1973, poor harvest in each of the world's major grain producing areas coupled with the reduction of reserve stocks in the US led to worldwide grain shortages and raised prices in the international market (Paulino, 1986). Speculation on primary commodities sent commodity prices in 1972-73 to levels not experienced since the Korean War in the early 1950s (De Vries, 1986). The high prices had devastating effects in poorer countries which of necessity had to import grain to feed their peoples

(Blaxter, 1986). It also raised concerns about food security and self-sufficiency in the developing world (Valdes, 1981; Wong, 1981; McCoy and Schuh, 1986; Bigman, 1985; Gittinger et al., 1987; Huddleston et al., 1984).

Many countries adopted policy measures aimed at increasing food security by expanding domestic food production. In many of these countries, increased production often meant expansion of agricultural areas at the expense of forestlands.

First Oil Crisis

In March 1973, the system of fixed exchange rate officially gave way to a system of floating exchage rates. The US dollar was again devalued during this time. Until then, the world economy was practically on a US dollar standard. The devaluation of the US dollar created problems for the world economy and was an important factor in the first oil crisis of 1973.

Oil producing countries had been feuding for years with powerful multinational oil companies over the sharing of oil revenues. When the dollar was devalued in 1973, oil producing countries demanded an increase in the posted price of oil on which was based the royalties paid by oil companies. Their contract had been denominated in US dollars and did not protect oil producing countries from losses caused by currency devaluations (Penrose, 1976). In the midst of these negotiations, the Arab-Israeli war broke out and Arab oil producers decided to use oil as a political weapon (Banks, 1983; Shwadran, 1986).

The price of Saudi marker crude increased from $3.01 to $5.12 per barrel in October 1973 to $11.65 in January 1974 (See Table 2-1). These sharp increases in the price of oil translated into trade deficits for oil importing countries and surpluses for oil exporters. It reduced real incomes and growth in oil importing countries and fueled inflationary pressures worldwide (Lin, 1981; Park, 1976).

Table 2-1. Annual average price of Saudi Arabian marker crude oil, in US$ per barrel.

Year	Price/Barrel
1967	1.33
1968	1.30
1969	1.28
1970	1.30
1971	1.65
1972	1.90
1973	2.70
1974	9.76
1975	10.72
1976	11.51
1977	12.40
1978	12.70
1979	17.26
1980	28.67
1981	32.50
1982	33.47
1983	29.31
1984	28.47
1985	27.88

Source: IMF. 1987. International Financial Statistics.

The higher oil prices encouraged energy conservation efforts the world over. In industrialized countries, consumers switched to coal, natural gas and other energy sources. In most developing countries, consumers increasingly turned to wood-based fuels which already supplied the major portion of energy needs (Pereira et al., 1987).

In 1974-1975, the world went into a recession. However, some commodities, notably sugar, coffee, and tea, enjoyed booming prices. The commodity price boom peaked in 1976 and lasted through 1977.

World prices of pulp and paper products also rose to unprecedented levels. Since developing countries were net importers of pulp and paper products, many countries found investment in pulpwood plantations very attractive.

The IMF’s New Role

With the collapse of the fixed exchange rate system, it became necessary for the IMF to redefine its function. During the early 1970s, the IMF began to assume the function of surveillance of exchange rate policies in order to contain inflation and excess international liquidity (De Vries, 1986).

In its new role, the IMF, together with the World Bank, was described by Lawrence (1986, p.5) as "an international state machine, custodian of financial stability, controller of balance of payments stability, examiner of nation-states’ economic policies, issuer of certificates of financial respectability and coordinator of world economic policy."

During this period, the IMF sought to increase its capacity to lend to developing countries experiencing temporary balance of payments deficits. The new role of the IMF was not unrelated to the massive surplus revenues of the Organization of Petroleum Exporting Countries (OPEC) that had to be recycled in the international financial markets (Park, 1976).

Following the first oil crisis, the IMF cushioned non-oil developing countries from increasing oil import bills by financing balance of payments deficits through the IMF's Oil Facility. Thus, oil-importing developing countries were spared the necessity of painful structural adjustments in their economies.

Credit Expansion

Following the lead of the World Bank and the IMF, other multilateral and private lending institutions also increased lending to developing countries after the first oil crisis. Even before the excess liquidity created by the oil price hikes, commercial banks had begun to turn their attention to developing contries. Multilateral lending institutions were also already beginning to respond to the clamor for increased development lending during the late 1960s (FAO, 1970; Ferguson, 1988; Darity and Horn, 1988). The oversupply of funds caused by OPEC surpluses simply prompted these lending institutions to aggressively seek clients among developing countries during the mid-1970s.

Most of the commercial loans were channeled to newly industrializing countries, such as Brazil and Mexico, and to middle income developing countries. These countries were considered better credit risks and, hence, received disproportionate shares of the loans from private commercial banks. Interest on these loans were based on the London Inter-Bank Offer Rate (LIBOR). Low income countries, on the other hand, relied mostly on concessional lending from official multilateral sources.

With increased competition among lending institutions, even countries with questionable creditworthiness were extended credit. During this period of credit expansion, there were strong elements of "loan pushing".[2] On hindsight, many authors put part of the blame for the present debt crisis on the institutions' overwillingness to lend during this period (Stallings, 1987; Korner et al., 1986; Payer, 1982; Wionczek, 1985; Darity and Horn, 1988).

Loan-financed Projects

Loans were made available for the finance of development projects in agriculture, forestry, energy, transport and other sectors. The projects were supposed to raise rural productivity and increase agricultural output. In South Asia, projects involved the promotion of the "green revolution" technology in cereal production. Lending to the forestry sector was mostly for establishment of tree plantations for pulp and paper which seemed a particularly attractive investment in light of soaring prices for pulp and paper products in the international market.

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[2] The "loan-pushing" literature dates back to the 1930s, spawned by the debt crisis of the 1920s. Darity and Horn (1988) review this literature.

In all sectors, there was a strong preference for large-scale projects such as multipurpose dams, plantations and agro-industrial complexes (Payer, 1982). Transmigration programs were also financed out of these development loans. In some countries, a significant part of borrowed funds lined the pockets of a "kleptocratic" elite (Bello et al., 1982; Korner et al., 1986).

Many loan-financed development projects have come under fire from various groups for the social and enviromental disruption they have caused (SAM, 1987). In many cases, the projects displaced communities many of which were resettled in forested zones. Natural forests were cleared in some countries to establish plantations[3] of fast-growing trees for pulp and paper or for fuel in dendrothermal plants.[4] Road construction and transmigration projects also destroyed vast areas of the Amazon forest (Mahar, 1989) and of forests in other tropical regions.

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[3] However, direct conversion of natural forest to plantations was a miniscule percentage of the amount of tropical deforestation. See Sedjo (1983).

[4] For example, see Anderson and Huber (1988).

IMF Conditionality

In 1976, the IMF drastically changed its policy. Signs of recovery from the 1974-75 recession in industrial countries, favorable prices for primary commodity exports, and, concern over mounting developing country debt prompted the policy change (Guitian, 1981; De Vries, 1987). Further lending was made conditional on structural adjustments undertaken by a borrowing country to accomodate the higher oil prices.

In 1977, the IMF decided to emphasize exchange rate changes to facilitate the adjustment. Real devaluations remain the preferred adjustment tool because they are believed to achieve a reduction in real income by increasing the price of tradable goods, thereby, contributing to decreased expenditures. They are also believed to cause a relative price change that makes exports and import-substitutes more profitable and imports more expensive. The resulting realignment in production and increased export earnings are supposed to correct a country's trade and payments imbalance.

The conditionality was based on the premise that many debtor countries have failed to completely adjust to global economic conditions because of excessive aggregate demand

and because of an allocation of expenditure that is biased against exports (Fishlow, 1985). Developing country debtors were asked by the IMF to restrain aggregate demand, control inflation and devalue their currency.

Demand restraint typically involved cut-backs in public outlays, elimination of subsidies, tax increases and increased prices for public services. These measures were meant to reduce fiscal deficits that contribute to aggregate demand and domestic credit creation. Nominal wages were contained to control inflation; high interest rate policies were used to encourage domestic savings.

These prescriptions forced upon developing countries have been controversial. Critics argued that, especially in poor countries, demand restraint and exchange rate and related price adjustments would not quickly lead to a switch of expenditures from domestic consumption to exports or to domestic production from imports; few exports are consumed locally and few imports have local substitutes (Dell, 1982; Payer, 1982; Korner, et al., 1986; Fishlow, 1985; Pereira, 1987; Crockett, 1981; Helleiner, 1983 and 1986; Loxley, 1986; Singh, 1986; Lawrence, 1986). Furthermore, critics pointed out that it takes time, something which the adjustment programs did not allow for, to expand agricultural or mineral export production in response to price incentives.

Devaluations can also be inflationary (Fishlow, 1985). With devaluation, producers shift resources from nontradable to tradable goods production while consumers switch from consumption of tradables to nontradables. Without concommitant fiscal and monetary policies to reduce aggregate consumption or increase investment, prices of nontradable goods will increase, contributing to inflation and making further devaluations necessary.

An inflationary condition, in turn, can affect people's and governments' perception and relative valuation of future benefits and costs. It could raise their effective discount rates, making immediate gains and immediate consumption much more attractive than would be the case in a non-inflationary situation. Liquidation of forests and other natural resources could appear very desirable.

Second Oil Crisis

From 1977 to the first half of 1978, world output and trade continued to recover from the 1974-1975 recession. However, growth in the industrial world was slow and uneven. Inflation with high unemployment, a condition which came to be known as "stagflation", persisted in industrialized countries and more severely in developing countries. The combination of slow growth in world trade and high domestic unemployment generated increased protectionist measures in industrialized countries. This frustrated the attempts of developing countries to expand their exports and to restructure their economies.

In late 1978, OPEC began to increase the price of oil in anticipation of acute oil shortages following the Iranian revolution. In early 1979, the oil supply shortage was estimated at 5% of global oil consumption and pushed spot market prices to over $40 per barrel (Lin, 1981). Part of these oil price increases may also have resulted from the US dollar devaluation in 1977 and again in 1978 (De Vries, 1987). The second oil crisis which lasted till 1980 made for even greater inflation worldwide.

Even oil-exporting countries were not immune from the effects of cost push inflation. OPEC members experienced severe deterioration in terms of trade because of the sharp increase in cost of imported manufactures.[5] It was also partly caused by the sizable depreciation of the US dollar (Lin, 1981).

In oil importing countries, the second round of oil price increases further increased the demand for firewood and charcoal as consumers sought cheaper substitutes for petroleum-based fuels (Pereira et al, 1987). The increased demand coupled with declining supply of fuelwood increased prices for wood fuels. It created what Eckholm (1980) called the "other energy crisis" for more than a third of the world's population, most of whom are in Asia.[6]

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[5] This phenomenon has been called the "Dutch disease". See Neary and Wijnbergen (1986), Kemp and Long (1984), Corden and Neary (1982), Valdes and Siamwalla (1988), Edwards (1986), Scherr (1989), Urrutia and Yukawa (1988).

In 1979, the IMF urged developing countries to establish an environment attractive to foreign investment rather that to accumulate more debt. During this time also, questions were being increasingly raised concerning the ability of non-oil developing countries to meet debt service payments. This was partly a reaction to the fact that low income sub-Saharan African countries have been having difficulty meeting debt service obligations as early as 1975. In all, since 1975, fourteen African countries have had successive annual debt rescheduling in the Paris Club, the main forum for relief from official loans to sub-Saharan Africa (World Bank, 1987b).

Meanwhile, in industrialized countries, inflation reached the double digits by 1980. The fight against inflation became the major policy concern since it was seen as a prerequisite for stimulating economic growth (De Vries, 1987). Interest rates increased as industrialized countries adopted restrictive fiscal and monetary policies through to the middle of 1982.

Debt Crisis

In 1981-1982, the world experienced its deepest and most prolonged recession in 50 years. International commodity prices declined sharply. The recession further shrunk developing countries' export markets and dealt a major blow to countries that had restructured their economies around their export potential.[7] High interest rates magnified debt service payments and proved devastating to countries that had borrowed based on variable interest rates.

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[6] Also refer to Leach et al. (1986).

Most debtor nations adjusted to high rates of interest by sharply reducing their imports. For many countries, this was accomplished at the cost of stalled development and falling per capita incomes (World Bank, 1983).

Growing lack of confidence in the ability of developing countries to meet their obligations caused lending institutions to drastically reduce credit. Terms of credit were shortened in 1980 and 1981 and private lending was severely cut back in the second and third quarters of 1982. On August 13, 1982, Mexico, an oil exporter and a country regarded among the least likely to default, announced that it could no longer meet its debt-service obligations.[8] Soon after this announcement, the flow of international credit to the developing world stopped.

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[7] More recent evidence suggests that export-led growth can not be considered a universal recommendation for developing countries, particularly for low income countries. See Singer and Gray (1988).

[8] For analysis of the 1980 debt crisis, refer to De Vries (1986), Lessard and Williamson (1987), Sachs (1989a, 1989b).

Meanwhile, other debtor countries sought additional funding to tide them over their liquidity crisis. In all these countries, the IMF insisted on implementation of conditionality measures in order to obtain the IMF's certification of creditworthiness which, in turn, is necessary for additional borrowing. Governments complied with the conditionality measures at great economic and political cost. Additional credit, however, was not forthcoming. Since 1982, debtor countries followed emergency stabilization programs geared towards generating very large trade surpluses in very short periods of time (Edwards, 1989). Most countries resorted to a combination of expenditure-reducing and expenditure-switching policies including currency realignment, imposition of capital controls, and import quotas. These adjustments necessitated interest rate increases and relative price adjustments or real devaluations.

The high political costs of these policies at first prevented governments from fully implementing the adjustment program. However, as the balance of payments crisis deepened and as alternative sources of funds became increasingly unavailable, governments had no choice. Since 1982, there has been a reverse flow of capital from major borrowers to the creditor countries. From the Latin American countries, it was estimated that $20 billion in 1982 and $30 billion in 1983 were transferred to creditor countries (Fishlow, 1985). In 1984, developing countries as a group turned from being net capital importers to net capital exporters (World Bank, 1987b).

In many highly indebted countries, efforts to contain aggregate expenditures were associated with increasing fiscal deficits as total tax revenues shrunk. The reliance of governments on inflationary financing became reflected in rapid rates of increase in consumer prices in 1984-1985 (Edwards, 1989; Dornbusch and Reynoso, 1989). Expansionary fiscal policies and exchange rate overvaluation may have exacerbated the problem by contributing to capital flight out of debt burdened countries (Cuddington, 1987).

By the end of the study period, there was massive impoverishment of the population in most of the developing world. Hardest hit were the low income countries in Sub-Saharan Africa and the newly industrializing countries of Latin America that had accumulated massive debt from private sources. Interest payments on these private loans varied with the market interest rate, which, at the time, was kept high by the budget deficit incurred by the Reagan administration in the United States (Dornbusch, 1987).

The debt of African countries, although small in absolute value, imposed a great burden on these countries. The poverty of many African nations is so acute that even a small amount of debt and interest payment can be extremely burdensome. Paradoxically, Africa, although less indebted than other regions, was more burdened by its debt (Sutcliffe, 1986).

Rediscovery of Agriculture

With the debt crisis, many developing countries again turned towards agriculture. Several factors accounted for this rediscovery of agriculture: growing political and social tensions emerging from high food prices; widespread malnutrition; stagnant peasant incomes in rainfed areas; the need to substitute for food imports; and the need to generate foreign exchange. Government efforts in this direction, however, have been hampered by budgetary constraints. Even then, in many countries, agriculture registered positive output growth while other economic sectors stagnated. For example, in Latin America, agricultural GDP rose 2% a year during 1980-84 compared with almost zero growth in total GDP (FAO, 1985a). India and Indonesia also managed to substantially increase their production of cereals. Although drought devastated some 25 countries in Africa between late 1982 and 1985, total food and agricultural production in Africa in 1985 registered an overall increase of 30% over 1984 levels.

In many countries, however, agricultural prices and farm income deteriorated in real terms. This deterioration resulted largely from real currency devaluations. In Latin

America, cereal producers were paid 43% less in real terms than in the early 1970s (FAO, 1985a).

While the specter of Malthusian food scarcity seemed very real in the 1970s, in the 1980s, there were no aggregate shortages of food supplies. Instead, the problem lay in food distribution and, in broader terms, in national and international income inequality (McCoy and Schuh, 1986).

By the 1980s, developing countries were reassessing their policy of food self-sufficiency. Despite efforts at increasing production, in most countries, the increased supply could not keep pace with increasing demand, particularly for cereals for animal feed (Sarma, 1986; Paulino, 1986). This led to the paradoxical situation characterized by greater import demand even as domestic production increased.

Unfortunately, foreign exchange shortages constrained the importation of food, fertilizer and other necessary inputs. Despite food surpluses and declining real grain prices in the international market, the food situation in the developing world in the 1980s was not much different from that of the previous decade (Timmer, et al., 1983; Butler, 1986). Developing countries have had to rely on domestic production and domestic resources. Under these conditions, natural resource stocks such as public forests became tempting and very vulnerable sources of additional arable land and foreign exchange.

Forest Products Trade

Between 1960 and 1980, tropical log production and trade expanded rapidly with three countries in Asia--Malaysia, Indonesia and the Philippines--dominating tropical wood trade. In 1980, log output from these three countries accounted for almost 50% of production in all tropical regions (UNECE/FAO, 1986). Brazil, Cameroon, Ivory Coast and Nigeria were other major producers. The bulk of tropical wood exports consisted of unprocessed roundwood.

Tropical logs flowed from exporting countries to developed country importers, mainly Japan, the US and Europe (Table 2-2). The direction of tropical wood trade closely corresponded to old colonial ties between the developing country exporter and the developed country buyer (Buongiorno et al., 1980-81).

Trade in tropical wood, however, was a small proportion of international forest products trade. As a group, tropical developing countries have been net importers of forest products particularly pulpwood, paper, newsprint, softwoods and other processed wood products (Erfurth, 1984; Schreuder, 1986; Kuusela, 1987; Breunig, 1987; Bourke, 1988).

The situation improved somewhat during the latter half of the 1970s when developing countries sought to develop and augment their wood processing capacity using funds mostly borrowed from international sources. Many countries begun instituting partial or total ban on export of unprocessed logs. This was a move aimed at increasing value added, achieving a more equitable distribution of benefits from forest products trade, and ensuring a steady supply of logs for the newly installed log processing facilities (Enabor, 1977; Laarman, 1984; UNECE/FAO, 1986; Kumar, 1986; Ngau et al., 1987; Kumar, 1988).

Table 2-2. Imports of hardwood forest products from tropical countries by major importers, 1960, 1970 and 1980 (in million cubic meters).

	1960	1970	1980
Japan			
Hardwood logs[a]	4.8	19.9	19.2
Sawn hardwood	-	0.3	0.6
Plywood	-	0.5	0.1
Veneer sheets	-	0.1	0.1
United States			
Hardwood logs[a]	0.3	0.1	-
Sawn hardwood	0.4	0.4	0.5
Plywood	0.5	0.2	1.0
Veneer sheets	0.1	0.2	0.1
Europe			
Hardwood logs[a]	3.6	6.4	5.9
Sawn hardwood	1.0	1.5	3.2
Plywood	0.1	0.2	0.7
Veneer sheets	0.1	0.1	0.2

Source: UNECE/FAO. 1986. European Timber Trends and Prospects to the Year 2000 and Beyond. Vol. 1. United Nations: New York.

[a] Include sawlogs and veneer logs.

In many countries, however, the ban remained largely on paper, thwarted by rampant smuggling. Nevertheless, by the end of the decade, developing countries were net forest products exporters.

The year 1980 was a peak year for developing country exports of forest products. However, with the global recession, the export value of roundwood, still the bulk of the wood exported, was reduced by about a third after 1980. Growth in production slowed and developing countries reverted to being net importers of forest products (FAO, 1985a).

By 1984, industrial wood production by developing countries was valued at $30 billion. They produced 94 million cu.m. of sawnwood, 17 million cu.m. of wood-based panels and 15 million tons of paper. Still, as a group, they imported about 25% of the paper they consumed, and 15% of the pulp input for local paper production. These proportions were even higher for Africa which was estimated to import 60% of its paper consumption.

CHAPTER 3
A CONCEPTUAL VIEW OF FOREST DEPLETION

The policy of tropical developing country governments relative to forest resource use can be examined in the context of cost-benefit decision process. If a government is economically rational, it would allow logging and forestland conversion to alternative land uses only if it perceives the net benefits to be greater than the cost of preserving the forest.

To a large extent, economic and political pressures such as described in the previous chapter define a government's perception and expectation of relative costs and benefits. Acquiescence to forest-destructive economic activities can be viewed as a response to these various pressures.

The decision to allow logging on public forests can be interpreted as a reflection of a government's willingness to risk deforestation given prevailing economic and political circumstances. Since logging can easily lead to deforestation particularly in areas of high population density, government approval of logging is often tantamount to implicit approval of deforestation.

In the following sections, forest depletion from government-authorized logging and forestland conversion will be linked conceptually to the government's optimizing calculus. First, however, some clarifications are in order.

Government: Policy and Behavior

As indicated in the first chapter, the government is a key element in the depletion process because of its role, through its forestry agency, as manager of public forestlands. Despite reference to "the government" as the decision-maker, it should be stressed that this in no way implies that governments are monolithic.

It is recognized that governments are made up of diverse, competing interest groups. Government policies are the result of the political struggle among these various groups and ultimately reflect the position of the dominant party or coalition of interests. The government's forest use policy referred to in the following sections is the result of this same process.

Furthermore, governments span the range from authoritarianism to democracy. Their policies may promote the interests of a few or the interests of many. In the optimizing calculus discussed below, expected costs and benefits of forest exploitation versus preservation are reckoned from the point of view of the government, a vantage point which is not the same as that of society as a whole.

Therefore, the level of forest depletion a government may consider optimal is not necessarily socially optimal. If ever, short-term political interests of a government seeking to stay in power will most likely tend to drive the politically optimal and the socially optimal levels of forest depletion farther apart.

Often, the beneficiaries of the government's decision to exploit forest resources are not the same ones who bear the costs of forest depletion. For example, liberal policy on wood harvesting is likely to benefit the politically influential forest products industry and urban consumers of processed wood products while hurting politically marginalized low-income communities dependent on the forest for their subsistence.

The model discussed in the following sections abstracts from all these complexities and focuses on the basic economics involved in a government's forest use decisions. Hyde's (1980) generalization of Faustmann's (1849) model was used to analyze a typical developing country government's decision to allow logging and conversion of public forests.[1] The model assumes that under any given macroeconomic condition, the government maximizes the net present value of expected net perpetual returns from a unit area of forestland under its control.

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[1] Jackson (1980) used a similar model to describe the US timber industry.

The net present value maximization model was used because of its conceptual generality and flexibility. It can describe the behavior of an authoritarian government and of a perfectly democratic government equally well through suitable redefinition of what and whose costs and benefits will be considered. Costs and benefits need not be limited to purely economic considerations. Political and other types of gains and losses can be incorporated in the analysis.

The behavioral assumption of net present value maximization may at first appear highly unrealistic when confronted with forestry codes mandating sustained yield forest management[2] in many tropical developing countries. However, the evidence shows that although many countries may nominally adhere to the system of selective logging and sustainable forest management, actual practices deviate radically from these principles (Repetto, 1987,1990).

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[2] Many authors have sought to reconcile the Faustmann criterion with the maximum sustained yield criterion. Among others, Samuelson (1976), Clark (1976), Bentley and Teeguarden (1965), Hyde (1980), and Chang (1983) showed that as the discount rate approaches zero, the two solutions tend to converge. Hellsten (1988) showed that the Faustmann rule is only a special case that can be associated with socially optimal sustained yield forestry. Tapan and Wan (1986) showed that the Faustmann solution is optimal when the future utility function is linear; if the utility function is increasing and strictly concave, the optimal solution converges to a maximum sustained yield solution. Others have shown that the relationship between the two criteria is ambiguous. For examples, see Hartmann (1976) and Binkley (1987).

Furthermore, in many countries, the government and local and foreign logging companies tend to be partners in forest exploitation. In fact, many logging concessionaires are state-owned or state-controlled corporations with substantial foreign participation or subsidiaries of multinational logging corporations. The lines of communication between the government and logging companies tend to be direct and, hence, the lag time between government policy decisions and forestry indusry response tends to be relatively short.

The Model

Conceptually, the forest can be considered a growing capital resource and the forestland, a fixed factor of production. For a representative unit area of forestland[3], the government's net present value maximizing problem can be represented as:

$$(1)\quad \pi(T,M;Z) = \underset{T,M}{\text{Max}}\ [PQ(T,M)e^{-\delta T} - cM - R\int_0^T e^{-\delta t}dt].$$

$PQ(T,M)e^{-\delta T}$ is the expected present value of the total revenue stream and $cM + R\int_0^T e^{-\delta t}dt$, the discounted expected total costs. P is stumpage price net of extraction cost; c is expected factor cost per unit of M, the management effort applied at t=0. Z is a summary descriptor of macroeconomic conditions and δ is the government's discount rate.

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[3] The model implicitly assumes constant returns to scale and homogeneity in forestland quality. It also considers only the timber output from the forest. This latter feature is consistent with the observed tendency of governments to dismiss non-timber forest products as insignificant (Peters et al., 1989).

R is expected land rent, the opportunity cost of keeping the land under forest. It is defined by the periodic payments to the land in its highest valued alternative use. At the extensive margin of economically productive forestlands, rent is zero.

The term $R\int_0^T e^{-\delta t}dt$ is the discounted value of this expected periodic return and is the rental value of the given unit of forestland for T years. If factor and output markets are perfectly competitive, the rental value equals the difference between optimal revenues and costs.

The volume of wood, Q, produced from a unit area of forestland depends on T, the growing period of trees in the forest, and on M. M, if any, includes both direct silvicultural effort as well as forest protection measures that indirectly affect productivity. It is assumed that all management inputs are applied at the start of the production cycle.[4]

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[4] These highly simplified assumptions are made in order to facilitate exposition. More complex versions and extensions of the Faustmann model have been used by various authors. The effects of changing prices, costs, interest rates, management intensity, taxation, and of introducing uncertainty and other modifications to the basic assumptions have been analyzed. For examples, see Heaps and Neher (1979), Nautiyal and Fowler (1980), Chang (1983), Reed (1984), Merz (1987), and Max and Lehman (1988).

In the context of successive production cycles on the same piece of forestland, T may be represented as the sum of the age of the trees at the time of harvest, and the time required for the trees to recover from the effects of previous logging operations. The necessary recovery period may be shortened by more intensive application of M.

When plotted over time, Q follows a logistic curve characteristic of biological production functions. A rapid growth phase is followed by a period of slow growth and eventual maturity. Incremental growth from incremental units of M is positive and diminishing.

If forestry is the highest valued use for the given unit of forestland, the government will choose to keep the land under forestry in perpetuity. Equation (1) can then be written as an infinite series. Assuming prices and all parameters are known and constant, successive optimal production periods or rotations will be of equal length (Hyde, 1980; Samuelson, 1976).

$$(2)\quad \pi(T,M;Z) = \text{Max } [PQ(T,M;Z)e^{-\delta T} - cM](1 + e^{-\delta T} + \ldots + e^{-n\delta T}),\ \text{or,}$$

$$(3)\quad \pi(T,M;Z) = \text{Max } [PQ(T,M;Z)e^{-\delta T} - cM](1 - e^{-\delta T})^{-1}.$$

The necessary first order conditions for a maximum can be obtained by partially differentiating equation (3) with respect to M and T and setting their derivatives equal to zero.[5] From these first order conditions, a number of implications can be drawn.

A government would expend the level of management effort that equates the present value of the marginal product of M with its factor cost.

(4) $\pi_M(T^*) = 0$ implies $PQ_M e^{-\delta T^*} = c$.

It is apparent from equation (4) that, at the optimal rotation length T^*, a permanent increase in P would be associated with greater levels of M.[6] Hence, as forestlands become scarce and as net stumpage prices increase, governments can be expected to adopt greater measures to protect existing forests, increase productivity, and hasten the regeneration of logged over areas.

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[5] The necessary first order conditions are:

(a) $\pi_M = [PQ_M e^{-\delta T} - c](1 - e^{-\delta T})^{-1} = 0.$

(b) $\pi_T = \{PQ_T(1 - e^{-\delta T}) - \delta[PQ - cM]\}e^{-\delta T}(1 - e^{-\delta T})^{-2} = 0.$

The second order conditions for a maximum are described by the following equations:

(c) $\pi_{MM} = PQ_{MM}e^{-\delta T}(1 - e^{-\delta T})^{-1} \leq 0;$

(d) $\pi_{TT} = \{PQ_{TT}(1 - e^{-\delta T})^2 - 2\delta PQ_T(1 - e^{-\delta T}) + \delta^2[PQ - cM]\} e^{-\delta T}(1 - e^{-\delta T})^{-2} \leq 0;$

(e) $\pi_{MM}\pi_{TT} > \pi_{MT}^2;$

(f) $\pi_{MT} = \{PQ_{MT}(1 - e^{-\delta T}) - \delta[PQ_M - c]\}e^{-\delta T}(1 - e^{-\delta T})^{-2};$

where, π_{MM}, π_{TT}, and π_{MT} are second partial derivatives.

[6] Equation (4) is implied by equation (a) in footnote 5 when the rotation length is fixed at the optimal level T^*.

Throughout history, governments have indeed reacted to forestland scarcity in ways consistent with this theoretical prediction. Examples include Tokugawa Japan, medieval Europe and the United States during the last century (Tucker and Richards, 1983; Richards and Tucker, 1988; Totman, 1989; Perlin, 1989).

A government would allow the forest to be logged when the value of an additional year's growth is just offset by the implicit loss incurred by postponing net harvest revenues for another year, i.e.,

$$(5) \quad \pi_T(M^*) = 0 \text{ implies } PQ_T(1 - e^{-\delta T}) = \delta PQ - \delta cM^*.$$

Equation (5) assumes the optimal level of management input M^*. $PQ_T(1 - e^{-\delta T})$ is the expected value of wood volume growth if the forest were to remain unharvested for another year. The term δPQ denotes revenues foregone due to the one-year delay in harvest while δcM^* denotes gains from delay in management expenditures. This last term equals zero if the government does not apply any management effort.

For the government, wood is both output and capital. When the tree is cut and the log marketed, the wood is output; when the tree is allowed to grow another year or longer, the same wood is capital. A major consideration in the decision whether or not to let the tree grow another year is the return that might be earned from investing elsewhere the capital which could be obtained by cutting the tree (Clawson, 1974).

As long as the timberstand is growing, the government's biological capital appreciates in value. However, since growth decreases beyond a certain stage, at some point, it becomes profitable to replace slow-growing mature timber stand with robust young growth.

In the mid-1970s, for example, many governments opted to replace slow-growing hardwood stands with fast-growing softwoods. The move was meant to shorten rotation length, increase the number of rotations, and, thereby, raise expected net revenues from a given area of forestland. The fact that tropical countries are net importers of processed softwood products provided added justification.

Extent of Government-Authorized Logging

Given the economic environment described by Z, what the government perceives to be the maximum returns or profits from a unit of forestland is defined by the structure of prices and the optimal levels of T^* and M^*.

$$\pi^*(T^*,M^*;Z) = [PQ(T^*,M^*;Z)e^{-\delta T} - cM^* - R \int_0^{T^*} e^{-\delta t}dt]. \tag{6}$$

A supply function can be derived from the profit function described by equation (6) through Hotelling's lemma.

$$(7) \qquad \pi^*_P = Q^* = \{[Q_T(1 - e^{\delta T*})]/\delta\} + cM^*/P.$$

Equation (7) describes the optimal volume of timber Q^* from a unit of forestland which the government will allow to be logged during each rotation of T^* years. If the government does not apply any management input, i.e., if $M = 0$, Q^* will depend only on the rate of discount.

The equivalent average annual supply of legally extractible timber per unit i can be represented as

$$(8) \qquad s_i^*(P;Z) = Q_i^*(P;Z) \;/\; T_i^*(P;Z),$$

where, a unit is defined as a hectare of a particular site class[7], i, of forestland. By summing across all hectares, H_i, of each site class and across all site classes, the aggregate volume of legally extractible timber can be obtained.

$$(9) \qquad S(P;Z) = \Sigma_i \; H_i s_i^*(P;Z).$$

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[7] Site class is a classification of forestland quality based on tree growth. It is used as a proxy measure for productive potential. See Hyde (1980), Leuschner (1984), Robinson (1988).

It can be argued that assuming the government calculates costs and benefits in the manner described above and, assuming logging companies extract all the timber the government designates as extractible,[8] S(P;Z) reflects and is consistent with the government's perceived optimal level of forest exploitation. Associated with this level of timber extraction is a level of forest depletion H(P;Z), which, arguably, is also optimal from the government's point of view.

$$H(P;Z) = \Sigma_i H_i = S(P;Z) \; / \; s, \tag{10}$$

where, s is average commercial timber productivity per hectare and H(P;Z) is total hectares of forest depleted by government-authorized logging. In the empirical analysis, an indicator variable for H(P;Z) was constructed from aggregate timber extraction data (Details are discussed in chapter 4.) It was then used as the dependent variable in statistical models estimated (See chapter 5).

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[8] When the government grants concessions, the logging firm can choose to log at any time within the duration of the concession. It could be safely assumed, however, that firms will log as early as they possibly can. This assumption is empirically supported by various studies which have characterized logging operations as akin to strip mining in which the object is to extract wood as fast and as thoroughly as possible. This tendency has been attributed in part to uncertainty and to the relatively short concession periods granted by most governments. See Repetto (1990), Porter (1988), Kumar (1986).

As the market price of tropical timber increases with favorable macroeconomic conditions, the government can derive revenues from logging forestlands previously considered extramarginal. The government will then be increasingly inclined to allow logging in these forests. The government will be similarly inclined if changes in the macroeconomic environment change relative value in favor of wood harvesting. However, as often happens, commercial exploitation of previously inaccessible or uneconomic forests eventually leads to population settlement and conversion to agriculture.

Forest Conversion to Agriculture

It has been argued that the crux of the deforestation problem is that public lands are not efficiently priced and, thus, fail to generate competitive land rent (Anas, 1988). To understand the impetus for government sanctioned clearing and conversion of tropical forests, it is necessary to examine the opportunity cost to the government of keeping the land in forestry.

Using equation (1) and assuming for the moment that forestry is the best use of the land, an expression for rental value at the optimal levels of M^* and T^* can be derived. This equation represents the returns to land in its most efficient and highest paying alternative use given the conditions described by the vector Z.

$$(11) \qquad R \int_0^{T*} e^{-\delta t} dt \quad = \quad PQ(T^*,M^*)e^{-\delta T*} - cM^*.$$

A general expression for the returns to optimal forest production on the same unit of land under the same macroeconomic conditions can also be derived. Using equation (3), returns to forestry can be expressed as

$$(12) \qquad \pi^*(1 - e^{-\delta T*}) \quad = \quad PQ(T^*,M^*)e^{-\delta T*} - cM^*.$$

For the government to be indifferent between allocating the land to forestry and another type of land use such as agriculture, the following condition must hold:

$$(13) \qquad R \int_0^{T*} e^{-\delta t} dt \quad = \quad \pi^*(1 - e^{-\delta T*}).$$

If agriculture provides the highest return to the land,

$$(14) \qquad R \int_0^{T*} e^{-\delta t} dt \quad > \quad \pi^*(1 - e^{-\delta T*}),$$

the government will incur an economic loss by keeping the land in forestry. There will then be pressure for the conversion of the forestland to agricultural use.

Conceptually, frontier settlement and forest conversion programs implemented by governments of many tropical developing countries can be considered a response to the condition described by equation (14). Such response is not unique to developing countries. In Europe, for example, forest cover decreased from 80-90% to 15-20% of the land area during its deforestation phase from the 5th c. B.C. to the 19th c. A.D. (UNECE/FAO, 1986).

Throughout most of history, agricultural expansion into frontier land has been the main means of increasing agricultural production. Clearing of tropical forests for agriculture in developing countries is consistent with this pattern. Hayami and Ruttan (1985) refer to this as the resource exploitation model of agricultural development.

Equation (14) describes a general situation which arises when P is low relative to the net price of alternative crops that could be grown on the land. This was manifested, for example, in the conversion of natural forests to plantations of coffee, oil palm, and other agricultural crops for export and for domestic use during the 1960s and 1970s.

The situation indicated by equation (14) also occurs when the cost of managing the forest is too high or when the government uses a high discount rate.

The Government's Effective Discount Rate

Forestry policies adopted in many tropical developing countries strongly suggest that governments tend to apply very high discount rates in their land allocation decisions. A high discount rate implies a heavier weighting of current versus future returns from a given unit of land. Therefore, it tends to bias allocation in favor of land use types that either bring immediate gains or have relatively short gestation periods.[9]

A high discount rate discriminates against forestry which requires decades for the trees to mature. Within forestry, a high discount rate discriminates against the production of slow-growing hardwood species and favors fast-growing softwoods.[10]

The effective rate of discount governments apply to intertemporal allocation decisions vary with the macroeconomic conditions at the time the decisions are made. The government's intertemporal preference, as expressed by the effective discount rate, is determined by a number of political and economic considerations.

In many countries, urgent need for basic subsistence makes immediate sources of revenues extremely important. A government that wishes to retain its political power must be able to meet basic demands for food, housing and energy of a growing population through imports or domestic production.

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[9] A high discount rate is believed to encourage more rapid resource depletion. However, this need not always be the case. See Farzin (1984), Pearce and Turner (1990).

[10] Grainger (1988) noted that forestry plantations are lopsidedly in favor of softwoods and fastgrowing hardwoods species. High grade industrial hardwood plantations account for less than one-fifth of total area of tropical forest plantations. He projected that logging of natural forests for high grade wood species will continue because production from plantations will not be adequate to meet future demand.

Both require commitment of funds which, often, are not available.

Forests are viewed by many governments as ready sources of the funds they need as well as expansion sites for agricultural production. Employment generated by the logging and wood processing industries provides additional incentive for forest exploitation.

Critical shortages of foreign exchange and inflationary conditions tend to increase a government's effective discount rate. They encourage the adoption of policies that favor foreign exchange-generating and foreign exchange-saving activities. Currency devaluations which increase the cost of imports could exacerbate foreign exchange shortages.

Since agriculture typically contributes a disproportionately high share to developing countries' export earnings, governments in financially-strapped countries constrained by arable land availability see a strong case for reallocating forestlands to agriculture. Under these conditions of financial and material difficulty, the pressure on governments to liquidate their stock of forests is particularly intense: the political and economic costs of forest preservation are extremely high.

CHAPTER 4
DATA AND VARIABLES

In this chapter, the key variables in tropical forest depletion suggested by the historical and conceptual discussions of the two previous chapters are identified and discussed. These were the variables used in the statistical models estimated.

The nature of available data and the procedures used to calculate the forest depletion indicator and the macroeconomic and demographic explanatory variables are described in the following sections. The possible connection between forest depletion and the explanatory variables are then explored.

Data: Sources and Characteristics

The raw data used in this study were obtained from various international statistical sources. The International Monetary Fund's International Financial Statistics was the main source of data on national income, aggregate prices and international exchange rates. Data on international debt came from the World Bank's World Debt Tables.

Publications of the Food and Agricultural Organization (FAO) were the main sources of agriculture and forestry data. The FAO Production Yearbook provided data on land use, population and cereal production while the FAO Trade Yearbook provided data on volume and value of exports and imports of cereals and selected agricutural commodities.

Forestry production and trade data came from the Forest Products Yearbook. Data on forest productivity and average rates of deforestation for 1976-80 were obtained from the Food and Agriculture Organization and United Nations Environment Programme's (FAO/UNEP, 1981a-1981d) Tropical Forest Resources Assessment Project Reports.

The quality of the raw data left much to be desired. There are always difficulties and problems involved in constructing a consistent data set from cross-country, time series data collected from various sources. The problems are magnified when developing countries are involved. Since facilities and mechanisms for data collection and processing are usually inadequate in these countries, data quality tends to be low. The poorer the country, the lower data quality tends to be.

There were also problems with consistency of definitions across data sources. As a result, different agencies reported different, although highly correlated, figures for the same statistic. For example, the GNP figures from the World Bank differed from those reported by the IMF. Population figures reported by the World Bank also differed from those reported by the FAO.

There were other pitfalls along the way. Indexed data had different base periods; at times, the base periods themselves were shifted. Units of measure used to report the data were also sometimes changed. This was particularly true of the FAO's land use, quantity and value data.

From the point of view of this research, perhaps, the most important feature of the data lay in the gross underestimation and underreporting of industrial wood extraction from tropical closed forests. Illegal logging, smuggling and bureaucratic corruption contributed significantly to underreporting.

Construction of Consistent Data Set

Considerable effort was undertaken to make the data series consistent across countries for the years under investigation. The data were all expressed in the same units of measure, base period (1980), and currency (US dollars).

Missing data were individually estimated using, whenever possible, highly correlated predictors from the same data source. When data on a variable were available from two different sources, missing values were estimated using figures from the other source as a predictor. For example, the World Bank's GNP figures were used to predict missing values from the IMF's GNP series. Information from other sources were also used to adjust inconsistent figures.

Despite these efforts, however, some degree of weakness remained in the final data set. This could not be helped where the raw data itself was weak and where alternative sources of information were unavailable. Nevertheless, as the results will indicate in later chapters, despite the imperfections, the data provided valuable insights on the linkage between macroeconomic factors and tropical forest depletion.

Still, the results of this study must be interpreted with caution. Because of the characteristics of the raw data, the trends and relative magnitudes of the parameter estimates are, perhaps, more instructive than the absolute values of the estimates themselves.

Subperiods

For purposes of this study, the period from 1967 to 1985 was divided into four subperiods: Period 1 (1967-71); Period 2 (1972-75); Period 3 (1976-80); and Period 4 (1981-85). The average value of each variable discussed below was calculated for each period.

Period 1 captured the waning years of the system of fixed exchange rates. Period 2 started with grain shortages, saw oil price increases, credit expansion and ended with a recession. Period 3 saw booming commodity prices, slow recovery, conditional lending and the second round of oil price increases. Period 4 started with a deep recession and saw painful adjustments as developing countries staggered under the burden of their debt.

Countries Included

There were 45 countries included in the study. Of these countries, eleven are in Central America and Carribean, seven in South America, seven in Asia, and twenty in Africa (See Table 4-1). Regions were coded as 1=Central America and Carribean, 2=South America, 3=Asia, and 4=Africa.

Income Categories

Countries were divided into three income categories: low income oil-importing countries (Income Group 1); middle income oil-importing countries (Income Group 2); and oil-exporting countries (Income Group 3). This grouping followed the World Bank's classification of member countries reported in the World Debt Tables based on per capita GNP as of year-end 1985.

Oil-importing countries with per capita GNP less than $400 were classified as low income and those with per capita GNP of $401 or more were classified as middle income countries.

Table 4-1. Classification of countries by region, income group and international credit status.

Central America:

Costa Rica[2,*]
Dominican Republic[2]
El Salvador[2]
Guatemala[2]
Haiti[1]
Honduras[2]
Jamaica[2,*]
Mexico[3,*]
Nicaragua[2]
Panama[2]
Trinidad & Tobago[3]

South America:

Bolivia[2,*]
Brazil[2,*]
Colombia[2,*]
Ecuador[2,*]
Paraguay[2]
Peru[2,*]
Venezuela[3,*]

Asia:

Burma[1]
India[1,*]
Indonesia[3,*]
Malaysia[2,*]
Philippines[2,*]
Sri Lanka[1]
Thailand[2]

Africa:

Burundi[1]
Cameroon[3]
Cent. African Rep.[1]
Ivory Coast[2,*]
Ethiopia[1]
Gabon[3]
Gambia[1]
Ghana[1]
Kenya[1]
Liberia[2]
Madagascar[1]
Nigeria[3,*]
Rwanda[1]
Sierra Leone[1]
Somalia[1]
Sudan[1]
Tanzania[1]
Togo[1]
Zaire[1]
Zambia[1]

[*] Highly indebted/ major borrower.

[1] Low income oil importer.

[2] Middle income oil importer.

[3] Oil exporter.

Nineteen countries belonged to the low income group. Fifteen of these low income countries are in Africa, three in Asia and only one, Haiti, in Latin America. Middle income countries, on the other hand, are mostly in Latin America. Of the nineteen countries in the middle income group, only three are in Asia and two in Africa. The seven oil-exporting countries are distributed more or less equally among the regions.

International Credit Standing

Countries were also classified into two groups based on the World Bank's assessment of their international credit standing and financial health as of year-end 1985.[1] The first group was composed of 15 countries considered to be major borrowers or highly indebted. The second group consisted of the 30 other countries not included in the first group.

Highly indebted countries are a group of borrowers that account for nearly half of all developing country debt. Eighty percent of this debt is owed to private creditors, mostly at variable interest rates. Majority of the highly indebted countries included in the study are middle income or oil-exporting countries.

Major borrowers, on the other hand, are countries with disbursed and outstanding long-term debt estimated at more than $17 billion as of year-end 1985. Countries such as India, Indonesia and Malaysia are major borrowers but are not considered highly indebted while Brazil, Mexico and Venezuela are considered to be both major borrowers and highly indebted.

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[1] World Bank (1987b), p.xli.

A country's international credit rating was considered an indication of its vulnerability to pressures from the IMF and World Bank. It was thought to reflect the degree of influence international lending organizations had over the country's policy-making. Since major borrowers and highly indebted countries were under greater pressure to increase exports, they were thought to be more inclined to "mine" their forest resources to improve their balance of payments and credit positions.

Indicator of Forest Depletion

The area of closed broadleaved forests industrially logged was used as the indicator of deforestation. This was justified by the high correlation between logging and deforestation and by the fact that broadleaved forests[2] constitute the majority of closed tropical forests. Of the estimated total of 1195 million hectares of tropical closed forests in 1980, 97% were broadleaved forests and only 3% were coniferous forests (FAO/UNEP, 1981a-1981d).

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[2] The FAO/UNEP (1981a) defined closed broadleaved forests by the following characteristics: (a) more than 50% of crown cover made up of broadleaved tree species; (b) a high proportion of the ground covered with various storeys and undergrowth; (c) absence of a continuous dense grass layer which allows grazing and spread of fires; (d) often, but not always, multistoreyed; and (e) may be evergreen, semi-deciduous, wet, moist or dry.

Admittedly, a larger proportion of total wood extracted from natural forests was used for fuel. Only about 200 million cu.m. of the 1400 million cu. m. of wood taken from tropical forests each year were used for industrial purposes (FAO, 1985). However, fuelwood typically came from open woodlands, not from closed forests. Since fuelwood was collected from previously logged and already degraded forests, in general, fuelwood collection did not represent new forest disturbance.

In contrast, industrial logging typically involved opening previously unexploited closed forests.[3] Therefore, the area of closed broadleaved forests logged could serve as an indicator of new forest disturbance, of the additional area of forest made vulnerable to agricultural conversion by roads and access trails put in place by logging operations.

The area of closed broadleaved forest logged, HI, was used as the dependent variable. It was calculated as

$$HI = FI / VAC,$$

where, FI is the total wood removed from natural forests for industrial use, in 1000 cu. m. of roundwood equivalent.

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[3] Some forests, however, are selectively logged more than once. See FAO (1974).

VAC, the volume actually commercialized, is the average volume of marketable wood in roundwood equivalent obtained per hectare of undisturbed closed broadleaved forest. It is an average measure of commercial productivity across all site classes of closed broadleaved forests and is expressed in cu. m. per hectare. VAC is a market-based definition of forest productivity: it is based solely on wood species for which commercial demand exists. With advances in wood technology, the VAC for a given area of forest increases as more species become economically valuable.[4]

HI was expressed in 1000 hectares. In terms of the discussion in chapter 3, HI represented the observed aggregated H(P;Z) in equation (10). FI and VAC corresponded to S(P;Z) and s, respectively.

The average area of forest logged each year during the period 1976-1980 was compared with available data on average annual deforestation in the 45 countries included in the study during the same period. (See Appendix Tables A-1 and A-2). The Pearson correlation coefficient between the two measures of forest depletion was .79 while the rank order correlation was .81. The high correlations suggest that countries which allowed larger areas of forest to be logged also experienced greater deforestation.

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[4] See FAO (1973) for details of VAC estimation in mixed tropical forests.

Underreporting of Industrial Wood Extraction

Recent information from satellite photos on the rate of exploitation of tropical forests showed that past FAO estimates were extremely conservative (Repetto, 1990). In view of the discrepancy between actual and reported figures, it is important to stress that the extent of forest depletion calculated from the FAO data indicate only the minimum estimated forest degradation due to logging.

It was argued in chapter 3 that the extent of industrial logging can be considered a reflection of a government's willingness to sanction forest destruction. Although the conceptual model discussed in that chapter implicitly assumed that governments have effective police power, the reality of illegal logging and the underreporting that it causes does not invalidate the argument.

Illegal logging is illegal precisely because it is undertaken without government permission. In cases of illegal logging, the government was clearly unwilling to authorize the depletion of the illegally logged forests. Therefore, the official figures, although they do not reflect the extent of actual damage to the forest, still reflect the government's intentions relative to the use of the country's forest stock.

The problem arises, however, in cases of corruption in which the government, or key officials in the government, secretly grants logging permits or concessions in exchange for political favors or personal financial gain.[5] In these cases, officially reported logging figures understate the willingness of the government to sanction forest depletion.

Price Indices

The unit export value in US dollars per cubic meter (roundwood equivalents) of tropical broadleaved sawlogs and veneer logs was used as an indicator of the price of tropical wood in the international market. It was converted to 1980 dollars using the GDP deflator and expressed as an index with 1980 as base year.

An index was also constructed using the unit export prices, P_i, of six major agricultural exports, i = banana, coffee, cacao, cereals, rubber and tea. These are the most common crops grown on previously forested lands and are important foreign exchange earners in many countries in the study.

The prices were weighted according to w_i, the crops' shares in their combined total export value.

$$\mathrm{AGPI} = \Sigma_i\, w_i P_i, \quad \text{where,} \quad w_i = x_i \,/\, \Sigma_i x_i .$$

AGPI was deflated by the GDP deflator and expressed as an index using 1980 as base year.

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[5] For examples, see Broad and Cavanagh (1989), Porter (1988), Repetto (1990), Payer (1982) and Asian Wall Street Journal (1989).

The unit export value index of tropical logs and the export price index of major agricultural crops were both expected to be positively related to forest depletion.

Income

Per capita gross national product, in 1980 US dollars, was used as an indicator of a country's level of economic development and effective domestic demand. Based on the line of argument used in chapter 3, higher income was hypothesized to be associated with greater forest depletion since, theoretically, higher income increases demand for both wood and agricultural products thereby increasing the opportunity cost of keeping the forest unexploited.

However, it could also be argued that if the pristine quality of the forest is a normal good, higher income could increase the demand for forest preservation. If the value of preservation demand is high enough, it may be optimal not to harvest the forest (Hartmann, 1976).

Following this argument, forest depletion and other forms of environmentally destructive natural resource use can be viewed as an indication of poverty (Mellor, 1988; FAO, 1985b). As income increases, forest depletion is expected to diminish. A solution to the problem of tropical deforestation therefore presents itself, namely, a higher level of income concommitant with a higher level of development.

Since higher income tends to both increase and reduce forest depletion, its net effect on the forest stock was really an empirical question. Nevertheless, it was thought very likely that higher income in developing countries during the study period was associated with a net increase in forest depletion. This was thought to be especially true in countries with per capita incomes very close to the subsistence level such that forest preservation remained a luxury. It was suspected that additional income in these countries was used to satisfy unmet needs rather than to protect the forest.

Real per capita income, however, does not take into account the manner in which income is distributed among societal classes. The importance of income distribution in issues of forest resource use and degradation has been pointed out by many authors (Bussink et al., 1980; Dasgupta and Ray, 1986; Bromley, 1989b). Unfortunately, cross-country, time series data on income distribution during the study period were unavailable for the majority of countries considered here.

This study considered the effects of income distribution only indirectly and imperfectly through the regional dummy variables. Several studies on income distribution have noted significant regional differences in distribution of, and access to, income and resources (See discussion on Land and Population below).

Debt Service

The expansion of international lending to developing countries was one of the major features of the world economy in the 1970s. Various authors have suggested direct links between international debt obligations and tropical deforestation. Many believed that the greater a country's debt burden, the greater the forest destruction.

In this study, the debt service ratio was used as the indicator of the resources necessary to service a country's international debt. The debt service ratio is a short-term measure which considers the availability of foreign exchange as the major constraint in meeting external obligations.[6] The higher the debt service ratio, the greater the debt burden on governments.

The debt service ratio was calculated as the ratio, in percent, of total debt service on long term public and publicly guaranteed private debt to total export earnings. By long term debt was meant debt with original maturity of over one year. Total debt service included both amortization and interest payments.

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[6] See Fishlow (1985) for discussion on the use of debt service ratio as a criterion for evaluating a country's financial position.

Real Exchange Rate Changes

Changes in the real exchange rate influence economy-wide allocation of resources. For example, in oil exporting countries, the real exchange rate plays an important role in "Dutch disease" through the transmission of the effects of the oil price booms to the rest of the economy.[7]

Broadly defined, the real exchange rate is the real worth of a foreign currency in terms of the domestic currency. It is a single relative price which represents the price of a basket of traded goods relative to that of a basket of nontraded goods. Traded goods, or tradables, are goods that are either imported or exported. Nontraded goods, also called nontradables or home goods, are goods that are neither exported nor imported because of artificial trade barriers or cost considerations. Many services, for example, are intrinsically nontradable.

In this study, the real exchange rate was operationally defined as the the bilateral real exchange rate between the domestic currency and the US dollar. The use of the US dollar is justified by the fact that during the study period, it was the dominant medium of international transactions as well as the major currency in developing countries' reserves (Gandolfo, 1987, II.25-II.28).

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[7] Increases in the price of oil generally result in real appreciation of oil exporting countries' currencies which, in turn, leads to increased production of nontradable goods and decreased production and employment in the rest of the non-oil tradable sector. For references, see footnote 5 in chapter 2.

The real exchange rate was calculated using the following formula:

$$RER = XR * (WPI / CPI).$$

XR is the nominal exchange rate expressed, using the price quotations system, in number of units of domestic currency per US dollar. An increase in this rate indicates a nominal devaluation of the domestic currency.

CPI, the consumer price index, is the domestic currency deflator and an index of domestic inflation. WPI, the US wholesale price index, is the US dollar deflator reflecting US inflation. The CPI and the WPI also serve as indices of the price of nontraded and traded goods, respectively.

While a government can attempt to control the nominal exchange rate, it has no direct control over the real exchange rate. For example, a government can apply different nominal rates to different activities to reflect different levels of protection or taxation. Modifications to the real exchange rate, however, is only indirectly possible through changes in the nominal rate.

Macroeconomic variables such as domestic and foreign money supplies, real incomes, interest rates, price levels and international balances all affect the real exchange rate. Massive external borrowing can lower the real exchange rate substantially while large capital exports can have the opposite effect (Valdes and Siamwalla, 1988). Real exchange rates can also move for autonomous reasons, for example, as a result of oil discovery or a drastic shift in terms of trade.

The mechanism behind real exchange rate movements is still not well understood;[8] however, its role in resource allocation is better known. When the exchange rate is overvalued such as happens when domestic inflation exceeds world inflation, resources tend to move away from export-producing sectors. Currency overvaluation lowers incentives for exportable goods production while encouraging imports, leading to deficits and declining international reserves.

A country that chooses to deal with its balance of payments problem through import restrictions and explicit tariffs rather than through real devaluations will lose its international competitiveness. A country that continuously incurs budgetary and balance of payments deficits financed by foreign borrowing or external assistance will see its real exchange rate drift to a level lower than would otherwise be, i.e., its currency will become overvalued.

Since agriculture is a tradable goods producing sector, currency overvaluation hurts both exportable and import-competing agricultural products (Timmer et al., 1983; Schultz, 1978; Lawrence, 1986). The products of the forestry sector, another tradable goods producing sector, are similarly hurt by currency overvaluation.

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[8] Meese (1990) surveyed models of exchange rate determination and concluded that as yet, no model explains real exchange rate satisfactorily.

For developing country governments, however, currency overvaluation may have benefits, even if only in the short run. Overvalued exchange rates protect the generally politically powerful urban consumers against high food prices. They also tend to divert the flow of purchasing power to the urban sector. Overvalued exchange rates essentially constitute a food subsidy to urban consumers. The resulting nutrition and health benefits in urban areas may provide some justification for such policy (George, 1979; Kumar, 1979; Edirisinghe, 1982; Kent, 1984).

However, a policy of currency overvaluation keeps agricultural prices low, contributing to the persistence of rural-urban income disparities. The devastating effects of such policies are perhaps most dramatically seen in Africa (Acharya, 1981; Lawrence, 1986; Iyega, 1988). Imbalance between rural and urban incomes significantly contribute to population movements.

As discussed in chapter 2, the IMF has advocated the use of nominal devaluations to reverse the effects of real currency overvaluation. Among others, this adjustment is thought to directly benefit the agricultural sector by providing greater incentives for agricultural production.

A devaluation favors agricultural exports and at the same time inceases demand for nontradable agricultural products which become more competitive. The consequent increase in the demand for cultivable lands raise land rent on existing arable lands and encourage agricultural expansion into marginal lands.

Real exchange rate devaluations which increase agricultural rent affect the stock of forest to the extent that agricultural expansion occurs at the expense of forestlands. Movements in the exchange rate which increase agricultural incentives encourage land use shifts away from forestry to agriculture.

Persistent real devaluations are likely to contribute to forest depletion in two ways. First, increased competitiveness of forest products following a devaluation is likely to increase wood harvesting and thus, directly encourage forest destruction. Second, where land shortage constrains agriculture, persistent devaluations are likely to make governments more inclined to allow logging and colonization as a prelude to forestland conversion to agriculture. In areas where the government does not provide effective police power and forest protection, increased incentive for agricultural production invites illegal cultivation of public forests under a condition of virtual open access.

Food Security

Increased instability in international food trade created a greater degree of insecurity in developing countries' food consumption.[9] Physical shortages caused a major portion of this insecurity during the early 1970s. By the mid-1980s, among the developing regions, only Africa continued to be plagued by physical food shortages.

Nevertheless, insecurity remained in many countries because of the financial constraints to food imports. Even after the shortage turned into a surplus, developing countries still faced the insecurity caused by the uncertain ability to finance immediate food consumption needs. The higher a country's food import bill the greater its food security problem.[10]

For most developing countries, the solution to the problem of food security became synonymous with food self-sufficiency through greater domestic production. Alternative measures such as stockpiling of food and foreign exchange were simply too expensive to be feasible alternatives (Huddleston et al., 1984; Reutlinger, 1982).

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[9] Trade in food grains grew by 4% per annum between 1960 and 1980 with an annual average variation from trend of 7%. See Butler (1986).

[10] For discussion of various aspects of the food security issue, refer to Johnson (1981), McCoy and Schuh (1986), Bigman (1985), Chrisholm and Tyers (1982), Schultz (1978), Huddleston et al. (1984), Valdez (1981), Paulino (1986), Mellor (1988), Sen (1982), and Cheng (1989).

Where arable lands were limited, the move towards greater domestic food self-sufficiency encouraged the clearing of forestlands for agriculture. To the extent that agriculture and forestry are competitive land uses, policies that sway land use allocation in favor of agriculture have implications for the stock of forestlands.

Self-sufficiency in agriculture, particularly in food, was deemed desirable for a number of reasons. First, it minimizes a country's political vulnerability concomitant with dependence on imported food supply. Second, it conserves scarce foreign exchange a country needs for its development efforts. Third, it reduces instability arising from fluctuations in import prices. Fourth, increasing domestic food production creates employment for a large agricultural population that could not be absorbed in other sectors and for whom opportunities for self-employment are severely limited by capital constraints.

Furthermore, since small farmers spend 60% or more of their additional income on locally produced, labor-intensive goods and services, increased rural incomes from greater agricultural production have large multiplier and linkage effects in the non-agricultural sector (Mellor, 1989). Thus, a policy of increased domestic food production simultaneously addresses the issues of rural poverty, hunger and unemployment in a self-reliant manner.

Despite their desire for self-sufficiency, however, developing countries tend to tax their agricultural sector, keeping production lower than would otherwise be the case. Typically, developing countries undervalue agricultural output by keeping prices artificially low, providing a disincentive to agricultural producers (Schultz, 1978).

Because of the importance of cereals in most developing countries' food needs, food self-sufficiency is often defined in terms of cereal self-sufficiency. Cereal production and staple food production are very highly correlated in most countries of Asia, Africa and Latin America where the correlation coefficient ranged from 0.81 to 1.00 during the period 1961-1976 (Valdes and Konandreas, 1981). Recent evidence showed that food intake and over-all nutrition are strongly dependent on domestic cereal production (Cheng, 1989).

Cereals account for a major portion of food imports. In the late 1970s, for example, only 2-3% of food imports of developing countries were non-cereals. Although there are significant regional variations, cereals constitute the bulk of caloric intake in the developing world (Valdes and Konandreas, 1981; Paulino, 1986; Sarma, 1986).

In this study, the domestic cereal production ratio (DCPR) was used as an indicator of a country's cereal self-sufficiency and of its vulnerability to international food market instability.

$$DCPR = [CERP / (CERP + CMQ - CXQ)] * 100\%,$$

where, CERP is cereal production, CMQ is cereal imports, and CXQ is cereal exports. All are expressed in 1000 metric tons. CERP + CMQ - CXQ measures domestic cereal consumption.

DCPR is the proportion of total cereal consumption that is domestically produced. The higher the ratio, presumably, the greater a country's self-sufficiency and the lesser its vulnerability to fluctuations in the international food market. Ratios in excess of 100% indicate that the country is a net exporter of cereals. Examples are rice exporters Burma and Thailand (See Appendix Table A-8).

DCPR is closely related to Paulino's (1986) cereal self-sufficiency ratio which also uses the proportion of domestically produced cereals as an indication of self-sufficiency in cereal consumption. The difference between the two is that DCPR did not consider changes in cereal stocks in calculating total cereal consumption. This difference could be very slight since changes in cereal stocks were often negligible in many countries.

As an indicator of food security and self-sufficiency, DCPR, just like Paulino's cereal self-sufficiency ratio, has certain limitations and must be interpreted with caution. Caution is particularly necessary in analyzing African countries for which data quality tended to be weak (Lele and Candler, 1981). A case in point is Ethiopia where the ratios were high and yet, hunger was experienced in epidemic proportions.

High ratios may be obtained through a policy of decreasing consumption through import controls even without increasing production. It is also possible for a country to be self-sufficient in the final output while remaining highly dependent on other countries for supplies of inputs such as fertilizers and pesticides.

Land and Population

Rural landlessness is a major driving force behind clearing of tropical forests. Rapid population growth, which creates an imbalance between population and land resources, and the institutional legacy of colonialism, which greatly contributes to inequality in access to available land, are important causes of landlessness.

The monoculture plantation system of agriculture practiced by the Europeans throughout Asia, Africa and Latin America is an example of a colonial institution that continues to affect land access. Under this system, the best lands were allocated to foreign planters or corporations while local farmers were crowded onto the most marginal lands (Bromley, 1989b; Sinha, 1984).

The FAO estimated that in 1980, about a quarter of the world's population had little or no land to meet even the barest minimum needs of the individual. Landlessness is a major determinant of chronic hunger and malnutrition. The households with the least access to land are also the hungriest households (Sinha, 1984; Kent, 1984; Timmer et al., 1983; Sen, 1982; George, 1979).

Nearly two-thirds of landless and near-landless households are in the Far East, one-fifth in Africa and one-tenth in Latin America. Seventy-one percent of the total agricultural households in the Far East are landless. The corresponding proportions for Africa and Latin America are 10% and 13%, respectively.[11] Landlessness is most severe in the countries in the Indian subcontinent, in Java and in the Philippines.

While landlessness in Asia could be attributed mostly to land scarcity, inequality in land access are important causes of landlessness in Latin America. The Gini coefficient of land concentration for Latin American countries lie around .8 compared to .4 to .6 for Asia and .3 to .5 for Africa (Bussink et al., 1980). The low concentration ratios for Africa are due, in part, to the predominance of communal land ownership which guarantees citizens use rights to the land (Bequele and Van der Hoeven, 1980; Gyimah-Brempong, 1988).

The total area of arable land increased in all regions of the developing world even as the percent of land under irrigation and multiple cropping rose.[12] Most of the increase in arable land were at the expense of land under permanent pasture and forests (Bilsborrow, 1987). The extensive margin of cultivation continued to be shifted outwards even as modern agricultural technology made land intensification possible in densely populated rural areas.

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[11] See Sinha (1984), tables 1 and 2, p.16.

Landlessness exacerbated by urban-biased development policies induced population movements[13] and encouraged forest destruction through "spontaneous" or government-supported colonization of the forest frontier. Many developing country governments have used frontier colonization and land resettlement as a means of achieving a better balance between land and population.[14] For many governments, resettlement on forestlands has decided appeal --it allows them to stay away from the politically sensitive issue of land reform.

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[12] This is based on FAO data for 1961-65 and 1976. See Bilsborrow (1987) p. 198.

[13] Refer to Lipton (1982) for an excellent analysis and review of the evidence on rural migration. He discussed two types of migration -- rural to rural migration and rural to urban migration. Better educated and skilled individuals migrate to urban areas. The unskilled and least educated follow a pattern of step migration to other rual areas. Many eventually end up as slash and burn farmers on forestlands. On the other hand, migrants to urban areas end up taxing the absorptive capacity of the labor market as well as urban infrastructures and services. Many never get past the peripheral urban slums. Governments have encouraged slum dwellers to return to the countryside, in some cases, by resettlement to frontier forest zones.

[14] Shrestha (1987), citing results of United Nations surveys in 1976, noted that 116 out of 122 developing countries have resorted to direct as well as indirect means of affecting a more favorable demographic distribution in rural and urban areas. The Harris-Todaro (1970) migration model provided the intellectual basis for government intervention in situations when the rate of migration or urban population density was deemed excessive.

Since the 1970s, resettlement became increasingly part of internationally financed regional development programs with infrastructure components that displaced rural populations. Governments have used resettlement programs to stem the tide of rural migration, achieve development goals and consolidate political control over frontier territory. The environmental and social costs of such a policy, however, have not been cheap.[15]

Both the governments' and individual households' responses to the conditions of landlessness have had important implications for the stock of tropical forests. In this study, the ratio of arable land to rural population, in hectares per person, was used as the indicator of land availability in the agricultural sector.

Population, in million individuals, was included as an explanatory variable. It also served as a scaling variable. All other things constant, a country with a larger population was naturally expected to have a greater magnitude of forest degradation.

The total area of remaining forests could have been used as a scaling variable. Unfortunately, land use data for the study period, particularly the data on land under forest cover, were highly unreliable. Definition of land use types and criteria employed in land classification varied from country to country. In some countries, classification of lands as forest was determined by their juridical status rather than by their vegetation cover (FAO, 1961, 1973; FAO/UNEP, 1981a-1981d).

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[15] For examples, see Renaud (1981); Rodwin (1970); Oberai (1983); Shrestha (1987); James (1983); SAM (1986); Mahar (1989).

CHAPTER 5
STATISTICAL ESTIMATION, TESTING, AND RESULTS

The previous chapter discussed the variables thought to influence forest depletion during the study period. In this chapter, the degree of influence of these variables will be empirically estimated. The statistical models, testing procedures and test results are reported in the following sections.

Statistical Models

The magnitude of tropical forest degradation during the study period was hypothesized to be a linear function of prices, income, population and the macroeconomic variables discussed in the previous chapter. Each variable's contribution in explaining tropical forest depletion can be measured by their estimated regression coefficients.

A Malthusian explanation for tropical forest depletion would have been supported by results showing that all explanatory variables except population had coefficients that were not statistically different from zero. Statistically significant coefficients on the economic variables, on the other hand, would indicate the importance of macroeconomic factors in the process of tropical forest depletion.

The following linear models were specified and estimated.

Model I: $Y_i = \Sigma_k \beta_{ik}X_{ik} + u_i$,

Model II: $Y_i = \Sigma_k \beta_{ik}X_{ik} + \Sigma_j \alpha_{ij}D_{ij} + u_i$,

Model III: $Y_i = \Sigma_k \beta_{ik}X_{ik} + \gamma_i C_i + u_i$,

where $i=1,2,\ldots n$; $k=1,2,\ldots 10$; and $j=1,2,\ldots 6$.

These models can be more compactly represented as

Model I: $\mathbf{Y} = \mathbf{XB} + \mathbf{u}$,

Model II: $\mathbf{Y} = \mathbf{XB} + \mathbf{DA} + \mathbf{u}$, and

Model III: $\mathbf{Y} = \mathbf{XB} + \mathbf{C\Gamma} + \mathbf{u}$.

X was a nx10 matrix of explanatory variables with the first column consisting of the unit vector. **u** was a nx1 vector of residuals with $E(\mathbf{u}) = 0$ and $E(\mathbf{uu'}) = \sigma^2\mathbf{I}$, **I** the identity matrix.

D was a nx6 matrix of dummy variables for region, income group and international credit standing (One dummy variable in each category was deleted). **C** was a nx1 vector denoting the interaction between the rate of devaluation and the dummy variable for a country's international credit standing.

A, **B**, and **Γ**, the regression coefficient vectors, were 6x1, 9x1, and 1x1, respectively. There were 9, 15, and 10 coefficients estimated in models I, II, and III, respectively. In each model, the first element of the **B** vector was the intercept term.

The average annual values of the dependent and independent variables during each of the four periods were used in the regressions. Since there were 45 countries, there were 45 observations per period. Thus, n=45 when the models were estimated for a single period and n=180 when they were estimated using the pooled data set.

Each model was estimated using least squares regression. The significance of individual regressors were tested using T-test. F-test was used to test the significance of the over-all regression and to test the restrictions implied by different model specifications.

Comparison of Model Specifications

Model I assumed common intercept and slope coefficients for all countries regardless of geographic region, income group and international credit standing. Model II retained the assumption of common slope coefficients but allowed the intercept term to vary differentially by region, income group and credit category. Model III assumed common intercept and slope coefficients on all variables except real devaluation. Countries belonging to different categories of indebtedness were allowed to respond differentially to real devaluations in model III.

The comparison of model I against model II for any given period was a simultaneous test for statistical significance of the intercept shifts across regions, income groups and international credit standing, i.e.,

$$H_o: \alpha_j = 0, \ j=1,2,\ldots,6.$$

The comparison of model I against model III tested the significance of differences in the response of forest depletion to real devaluation in countries belonging to different credit categories during a given period. It was a test of the null hypothesis

$$H_o: \gamma = 0.$$

The restrictions were tested at the .01 level of significance using the F-statistics calculated from the models' residual sums of squares. The high level of confidence maintained in the tests was in keeping with the recommendation of Leamer (1978) and others who warned that in large samples, the calculated F-statistic tends to be large, making the rejection of the null hypothesis more likely. For larger samples such as the one used in this study, it was suggested that the significance level be adjusted downward.

Table 5-1 presents the test results. The F-test failed to reject the hypothesis that the coefficients of all dummy variables in model II were simultaneously equal to zero in each period, implying that model II could be adequately respresented by model I.

Model III could also be adequately represented by model I in all except the third period when the coefficient of the interaction term was statistically non-zero at the .01 significance level.

Table 5-1. Calculated F-statistics used to compare model specifications.

Period	Model I vs. Model II	Model I vs. Model III
Period 1	0.50	0.20
Period 2	0.60	0.74
Period 3	0.62	11.00***
Period 4	0.21	3.48
Degrees of Freedom		
q	6	1
n-k	30	35

*** significant at 0.01

Test for Multicollinearity

To test for linear dependence among explanatory variables, condition numbers were calculated and examined. The condition number of the matrix of explanatory variables is the square root of the ratio of the largest eigenvalue to the smallest eigenvalue. A large condition number indicates a high degree of linear interdependence among explanatory variables. As a rule of thumb, condition numbers around 5 or 10 denote weak interdependence. Moderate interdependence is indicated by condition numbers around 30. Condition numbers close to 100 denote strong linear interdependence among explanatory variables (Besley et al., 1980).

The variance decomposition proportions of each eigenvalue were also examined. They indicate the proportion of the variance of the estimate accounted for by each principal component associated with each of the eigenvalues. Multicollinearity is present when a component associated with a high condition number contributes substantially to the variance of two or more variables. Variance proportions greater than 0.50 are considered large for this purpose.

Tables 5-2 presents the condition numbers by model and by period. They indicated only weak to moderate linear interdependence among the explanatory variables. Based on these results, multicollinearity was not considered a problem in estimating all three models in each of the four periods.

Table 5-2. Condition numbers, by model and period.

	Model I	Model II	Model III
Period 1	20.56	26.45	25.52
Period 2	14.02	18.43	14.59
Period 3	20.54	27.84	21.33
Period 4	20.11	31.33	20.90
All Periods	14.42	18.78	14.74

Tests for Heteroscedasticity

The Breusch-Pagan (1979) test and White's (1980) test were used to statistically test the null hypothesis of homoscedasticity of the error terms from each model in each of the four periods, i.e.,

$$H_0\colon \sigma_{t1}^2 = \sigma_{t2}^2 = \sigma_{t3}^2 = \ldots \sigma_{tn}^2 \quad \text{for} \quad t=1,2,3,4.$$

Breusch-Pagan Test

The Breusch-Pagan test uses the ordinary least squares residuals and is based on the χ^2 statistic[1]. It assumes the disturbances from each model to be normally and independently distributed with variance

$$\sigma_{ti}^2 = h(\mathbf{g}_{ti}'\theta),\ i=1,2,3,\ldots n \text{ and } t=1,2,3,4.$$

$\mathbf{g}$ is a vector of variables suspected of causing the heteroscedasticity in the error terms. h( ) denotes an unspecified functional form and θ is a vector of coefficients unrelated to the model's coefficients. The first element of θ equals unity.

When all except the first element of θ are equal to zero, the null hypothesis of homoscedasticity is supported since the variance will then be $\sigma_i^2 = h(\theta_1)$, constant over all i.

In implementing the test, vector $\mathbf{g}$ included all the explanatory variables in model I. The calculated χ^2 test statistics are presented in Table 5-3. Test results rejected the null hypothesis of homoscedasticity at the .01 level in all instances, indicating some heteroscedasticity in the residual variances from each model in all periods.

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[1] For details, refer to Breusch and Pagan (1979). The test is also described in Johnston (1984) and in Judge et al. (1985).

Table 5-3. Calculated χ^2 statistics for Breush-Pagan test, by model and period.

	Model I	Model II	Model III
Period 1	100.48	92.94	105.07
Period 2	94.42	80.35	90.54
Period 3	133.32	113.40	125.09
Period 4	178.26	164.26	191.37

Note: All χ^2 statistics had 8 degrees of freedom and were significant at 0.01.

White's Test

To determine whether the inconsistency of the covariance matrices due to the presence of heteroscedasticity was serious enough to warrant correction,[2] White's test was employed. The procedure is based on the following principle.

Under homoscedasticity, V and U are both consistent estimators of the same covariance matrix.

$$V = n^{-1}\Sigma_i \hat{e}_i^2 X_i' X_i \quad \text{and}$$

$$U = \sigma^2(\mathbf{X}'\mathbf{X}/n)^{-1},$$

---

[2] It was not possible to estimate a seemingly unrelated regression (SUR) model because the number of countries was larger than the length of the available time series data. See Maddala (1977) for details.

where, $\hat{\sigma}^2 = (n-K)^{-1}\hat{e}'\hat{e}$ is the least squares variance estimator, $\hat{e}$ the vector of least squares residuals.

With heteroscedasticity, the least squares convariance matrix estimator is inconsistent so that V and U tend to diverge.[3] White suggested using the difference between V and U to assess whether or not the inconsistency of the covariance matrix is statistically significant. The test statistic

$$nR^2 \sim \chi^2\ (p(p+1)/2)$$

was introduced for this purpose. R^2 is the squared multiple correlation coefficient from the artificial regression

$$\begin{aligned} \hat{e}_i^2 &= a_0 + a_1\psi_1 + a_2\psi_2 + \ldots\ a_{p(p+1)/2}\psi_{p(p+1)/2}, \\ &= a_0 + \Sigma_k\ \Sigma_r\ a_m X_{ik} X_{ir}, \end{aligned}$$

where, $i=1,2,\ldots n$; $k=1,2,\ldots p$; $r=1,2,\ldots p$; and $m=1,2,\ldots (p(p+1)/2)$.

ψ_i is a 1 x $p(p+1)/2$ vector containing the elements of the lower triangle of the matrix $X_i'X_i$; $a_0, a_1, \ldots a_{p(p+1)/2}$ are the artificial regression coefficients; and $\hat{e}_i^2$ is the i^{th} squared residual from the model being tested for heteroscedasticity.

White noted that the artificial regression can fail identically if the estimating equation contains a constant term or if X_i contains a constant and polynomial terms. In these cases, he recommended dropping the redundant terms and adjusting the degrees of freedom accordingly.

---

[3] White (1980) discussed the conditions when heteroscedasticity does not lead to the divergence of the two covariance estimators.

In performing the tests, it was necessary to drop the dummy variables and the interaction terms in models II and III, respectively. The arable land ratio also had to be dropped from all three models. Thus, there were p=8 variables included in the **X** matrix. The calculated χ^2 had $p(p+1)/2 = 36$ degrees of freedom.

Results of the test indicated that the inconsistency of the covariance matrix in each period was not statistically significant at both the .05 and .01 levels (See Table 5-4). Therefore, the least squares covariance matrices were adequate for hypothesis testing.

Table 5-4. Calculated χ^2 statistics for White's test, by model and period.

	Model I	Model II	Model III
Period 1	44.94	44.95	44.97
Period 2	44.93	44.39	44.87
Period 3	44.97	44.81	44.79
Period 4	44.77	44.83	44.71

Test for Pooling Data Across Periods

The appropriateness of pooling the data for each period into one large data set was determined using Bartlett's test for homogeneity of error variances and the F-test for structural change over time.

Test for Homogeneity of Error Variances

Homogeneity of the error variances across the four periods was a precondition for data pooling. The Bartlett test was used to determine whether this condition was satisfied.[4]

The Bartlett test is based on the χ^2 distribution with T-1 degrees of freedom. The following statistic was used for the test.

$$(\Sigma_t\ (n_t - 1))\ln s^2 - \Sigma_t\ (n_t - 1)\ln s^2_t \sim \chi^2(T-1),\ t=1,..T.$$

T=4, the number of periods being compared, s^2_t represents the error variance for period t, and s^2, the weighted average error variance using the period variances as weights.

The null hypothesis H_0: $\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \sigma_4^2$ was tested against the alternative hypothesis H_1: $\sigma_1^2 \neq \sigma_2^2 \neq \sigma_3^2 \neq \sigma_4^2$. Results of the test are presented in Table 5-5.

The null hypothesis of homogeneous error variances across periods was rejected at the .01 level in all three models. Therefore, based on the results of the Bartlett test, the data could not be pooled.

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[4] The test is discussed in Bartlett (1937), Sokal and Rohlf (1981), Johnston (1984).

Table 5-5. Results of Bartlett test.

	χ^2	D.F.	Prob
Model I	111.12	3	0.000
Model II	115.00	3	0.000
Model III	104.53	3	0.000

The Bartlett test, however, is a very stringent test. Sokal and Rohlf (1981) noted that the test is unduly sensitive to deviations from normality in the data. Rejection of the null hypothesis of homogeneity may sometimes reflect deviations from normality rather than non-uniformity in the error variances.

Test for Structural Change

If the Bartlett test had indeed wrongly rejected the hypothesis of homogeneity of error variances, can the data be pooled so that a single equation can be estimated for all periods? To answer this question, a test was conducted using the F criterion made famous by Chow (1960).[5] This was a test to determine whether the data could be pooled conditional on the assumption of equality of error variances across periods.

The null hypothesis maintained that the regression equations were homogeneous across periods. Under the assumption of uniform variances and non-autocorrelated errors, this constituted a test for structural change.

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[5] Maddala (1977) noted that Chow's work was preceded by Rao (1952) and by Kempthorne (1952).

In the regression framework, structural change is defined as a switch in a regression equation and is manifested by statistically significant change in one or more regression coefficient (Broemeling and Tsurumi, 1987; Hsiao, 1986; Johnston, 1984). In the context of this study, structural change would indicate that the relationship between forest depletion and the explanatory variables changed with changing global economic conditions.

The F statistic was used to test the restriction that the intercept and slope coefficients were equal in all periods. The test statistics were constructed from the sums of squared errors obtained from the least squares regressions.

$$F = \frac{(URSS - RSS) / q}{URSS / n - k} .$$

The unrestricted residual sums of squares (URSS) were calculated by adding the sums of squared errors from the period by period estimates of the models (unrestricted because the coefficients were allowed to vary from one period to another). The restricted sums of squared errors (RSS), on the other hand, were calculated from the residuals generated from estimating the models using the pooled data.

The degrees of freedom in the numerator, q, indicated the number of restrictions implied by the move from the individual period estimation of the models to the pooled estimation. This equalled the difference between the degrees of freedom of URSS and RSS.

The analysis for structural change in model I tested the following implied restrictions:

$$\beta_{1k} = \beta_{2k} = \beta_{3k} = \beta_{4k}, \qquad k=1,2,\ldots 9.$$

In addition to these restrictions, analysis for structural change in model II also tested the following restrictions:

$$\alpha_{1j} = \alpha_{2j} = \alpha_{3j} = \alpha_{4j}, \qquad j=1,2,\ldots 6.$$

The restrictions implied by the test for structural change in model III included the above restrictions on β and the following restrictions on γ:

$$\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4.$$

Test results showed no statistically significant change in the coefficients of model II. However, they indicated significant structural change in models I and III (See Table 5-6). Thus, given homogeneous error variances, while model II could be estimated using the pooled data, models I and III had to be individually estimated by period.

The significant change in the coefficients of models I and III suggests that the extent of influence of the explanatory variables on forest depletion varied over the four periods. It could be interpreted as an indication of the effect of changing global economic conditions on the character of tropical forest depletion during the study period.

Table 5-6. Results of test for structural change.

	Model I	Model II	Model III
RSS	1623.26×10^5	1558.77×10^5	1337.15×10^5
d.f.	171	165	170
URSS	1124.29×10^5	1048.66×10^5	980.85×10^5
d.f.	144	120	140
q	27	45	36
F-statistic	2.37^{***}	1.30	1.70^{**}

** significant at 0.05 level.
*** significant at 0.01 level.

Regression Results

Regression coefficient estimates and their standard errors are reported and discussed in the following sections. Significant t-statistics of individual variables are indicated by asterisks in the tables of results. F-ratios used to test the significance of the over-all regression are reported at the bottom of the tables.

Although tests of significance are usually conducted only at the .01 and .05 levels, the tables also report statistical significance at the .10 level. In view of the quality of the available data, a 90% level of confidence in the coefficient estimates was deemed reasonable. Readers demanding more rigor in the tests can simply ignore variables that are significant only at the .10 level.

Tropical Forest Degradation, By Period

Regression results indicating the influence of macroeconomic and demographic factors on tropical forest degradation are presented in Tables 5-7 to 5-9.

F-tests indicated that the over-all regressions were statistically significant in each period in the three models. In models I and III, the F-ratios were significant at the .01 level in each period. In model II, the F-ratios were also significant at the .01 level except during the fourth period when the F-ratio was statistically significant only at the .05 level.

The explanatory power of all three models was highest in period 1 and lowest in period 4. With major changes in the global economy and in developing countries' economies along with them, the driving forces for tropical forest depletion apparently became more complicated than could be captured by linear functional relationships.

During the relative stability of the first period, the linear models specified in this study explained over 80% of the variation in the area of closed broadleaved forests industrially logged in tropical countries. By the fourth period, the same linear specifications were able to explain only about 50% of the variation in the dependent variable.

Table 5-7. Model 1: Coefficient estimates by period (Numbers in parenthesis are standard errors).

Variable	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Constant	-500.27*	-1350.48***	-2373.43**	2977.52*
	(232.27)	(311.23)	(898.27)	(1456.84)
Per Capita Income	0.02	0.34***	0.40*	-0.35
	(0.07)	(0.05)	(0.17)	(0.34)
Log Export Value Index	1.42***	-0.57	-8.11	19.65
	(0.38)	(0.66)	(4.76)	(10.12)
Agric. Export Price Index	-0.33	1.45	-1.36	-3.07
	(0.39)	(0.79)	(3.46)	(8.69)
Debt Service Ratio	-11.26	-32.99*	-25.56	-10.16
	(11.59)	(14.76)	(22.03)	(30.91)
Real Devaluation Rate	8.99	-0.02	83.98***	14.90**
	(7.34)	(2.50)	(22.57)	(5.86)
Domestic Cereal Prodn. Ratio	4.53	14.54***	21.74**	7.99
	(2.54)	(3.43)	(8.68)	(11.34)
Population	0.95	1.93*	2.14	2.69
	(0.71)	(0.86)	(1.52)	(2.01)
Arable Land Per Ag. Capita	67.07	10.83	856.50	2319.47***
	(63.56)	(146.51)	(597.92)	(710.50)
R-square	0.85	0.70	0.58	0.46
Adjusted R-square	0.82	0.64	0.48	0.35
F-Ratio	25.72***	10.71***	6.09***	3.90***

* Significant at 0.10 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

Table 5-8. Model II: Coefficient estimates by period (numbers in parenthesis are standard errors).

Variable	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Region 1^a	-37.98 (156.87)	78.98 (252.42)	315.83 (544.44)	-3250.63 (2181.59)
Region 2^a	-181.42 (185.00)	113.56 (308.86)	343.24 (696.75)	-657.52 (844.11)
Region 3^a	20.76 (170.18)	383.19 (277.40)	-333.85 (579.39)	-761.91 (1069.80)
Income Group 1^a	-237.06 (162.77)	123.60 (280.81)	241.51 (634.32)	-121.78 (893.33)
Income group 2^a	-80.84 (139.17)	227.45 (227.02)	370.41 (519.86)	5.35 (1029.49)
Debt Group 1^a	-70.72 (165.67)	-31.63 (232.65)	457.60 (524.74)	639.08 (841.65)
Constant	-368.45 (282.05)	-1540.49^{***} (401.08)	-2560.22^{*} (1199.17)	-198.62 (922.45)
Per Capita Income	0.00^{b} (0.08)	0.35^{***} (0.07)	0.45^{*} (0.20)	-0.28 (0.45)
Log Export Value Index	1.53^{***} (0.47)	-0.69 (0.73)	-11.88^{*} (5.78)	22.88 (11.89)

Table 5-8. continued.

Variable	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Agric. Export Price Index	-0.12 (0.46)	1.87^{*} (0.87)	-1.23 (3.97)	-5.11 (10.66)
Debt Service Ratio	-5.13 (13.01)	-41.94^{**} (16.95)	-42.95 (26.60)	3.89 (40.45)
Real Devaluation Rate	8.80 (9.00)	0.59 (2.66)	94.03^{***} (26.32)	15.05^{*} (6.55)
Domestic Cereal Prodn. Ratio	4.32 (2.71)	13.50^{***} (3.76)	25.03^{*} (9.65)	5.97 (14.47)
Population	0.81 (0.85)	1.74 (1.06)	2.20 (1.94)	3.42 (2.76)
Arable Land per Agric. Capita	89.94 (71.94)	100.46 (168.77)	639.49 (679.09)	2500.70^{**} (873.12)
R-square	0.87	0.74	0.62	0.49
Adjusted R-square	0.80	0.61	0.45	0.25
F-Ratio	13.69^{***}	5.97^{***}	3.52^{***}	2.03^{*}

* Significant at 0.10 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

[a] Dummy variable.
[b] Less than 0.005.

Table 5-9. Model III: Coefficient estimates by period (numbers in parenthesis are standard errors).

Variable	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Constant	-430.09	-1328.61***	-1839.31*	-2351.77
	(281.51)	(313.39)	(810.77)	(1448.63)
Per Capita Income	0.01	0.33***	0.32	-0.25
	(0.07)	(0.06)	(0.15)	(0.34)
Log Export Value Index	1.49***	-0.53	-8.38	16.65
	(0.41)	(0.66)	(4.21)	(9.92)
Agric. Export Price Index	-0.34	1.47	1.18	-1.74
	(0.40)	(0.79)	(3.15)	(8.43)
Debt Service Ratio	-11.73	-33.84*	-50.60**	-32.95
	(11.77)	(14.85)	(20.90)	(32.30)
Real Devaluation Rate	-0.64	-0.32	48.09	8.08
	(22.54)	(2.54)	(22.71)	(6.74)
Cereal Self-Sufficiency Ratio	4.17	14.33***	19.68**	10.12
	(2.69)	(3.45)	(4.71)	(11.02)
Population	0.89	1.72*	1.18	1.90
	(0.73)	(0.89)	(1.38)	(1.99)
Arable Land per Agric. Capita	70.66	-2.12	733.99	1768.71*
	(64.77)	(147.81)	(530.21)	(748.08)
Debt Group 1 * Devaluation[a]	-8.82	7.49	51.08***	15.30
	(19.50)	(8.71)	(15.40)	(8.21)
R-square	0.85	0.71	0.68	0.51
Adjusted R-square	0.81	0.64	0.59	0.39
F-Ratio	22.38***	9.53***	8.14***	4.09***

* Significant at 0.10 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

[a] Interaction with dummy variable

The results also showed the constant term to be consistently negative and statistically significant during the second and third periods in all three models. The constant term was significant at the .01 level in period 2 in models I, II and III. In period 3, the constant terms were significant at the .05 level in model I and at the .10 level in model s II and III, respectively.

In model I, the constant term was also significantly negative at the .10 level in periods 1 and 4. However, the constant terms in models II and III were not statistically significant during the first and fourth periods.

The negative constant terms suggest that the explanatory variables had to be larger than some minimum level before the associated forest degradation was observable.

Period 1. During the first period, the export value index of tropical logs was the only statistically significant variable. The coefficients of this variable were significant at the .01 level in the three models.

Estimated coefficients ranged from 1.42 to 1.53, implying that about 1420 to 1530 additional hectares of closed broadleaved tropical forests were industrially logged for every percentage point increase in the unit export value index of tropical logs.

The overwhelming significance of the export value index, however, has to be interpreted with caution.

Although there was no serious problem with multicollinearity according to the condition numbers, it should be pointed out that prices and income tended to move together during the first period, more than in any other period. It is possible that the influence attributed to the the export value of tropical logs may have included some of the effect of income and agricultural export prices.

Period 2. In period 2, per capita real income and the domestic cereal production ratio were the most statistically significant explanatory variables in all three models. The coefficients of both variables were positive and significant at the .01 level.

Estimated coefficients of per capita income ranged from 0.32 to 0.35 while those of the domestic cereal production ratio ranged from 13.5 to 19.6. These coeffient estimates indicate that from 320 to 350 additional hectares of closed broadleaved forests were logged with government approval for every dollar increase in per capita real income. Actual logging, including illegal logging, was perhaps many times more than what these estimates suggest.

Forest degradation during the second period was more affected by increasing domestic production of cereal grains. Coefficient estimates suggest that every percentage point increase in the domestic cereal production ratio was associated with harvesting of an additional 13.5 to 19.6 thousand hectares of forest.

The debt service ratio was another significant explanatory variable in period 2. Its coefficients were significant at the .05 level in model II and at the .10 level in models I and III. The debt service ratio had negative coefficients ranging -33 to -51. They indicate that the magnitude of industrial wood harvesting and associated forest degradation decreased with increasing debt service ratio.

These results concerning debt service were counter to apriori expectations. They suggest that during the early 1970s, less industrial logging of closed broadleaved forests occurred in countries with proportionally greater debt service obligations relative to export earnings.

For every percentage point increase in the debt service ratio, the area of closed broadleaved forests logged decreased by 33 to 51 thousand hectares. This negative relationship could be a manifestation of the effect of higher fuel prices which made logging operations more expensive. However, the consistently negative, although not statistically significant, coefficient on the debt service ratio even during periods of relatively low oil prices casts doubt on this interpretation.

The negative relationship between forest degradation and debt service could more plausibly be interpreted as evidence that greater borrowing made it less necessary for governments to rely on revenues from commercial exploitation of tropical forests. Without the safety net provided by liberal credit during the second period, most likely, governments would have increased forest harvesting much as they did during the credit crunch of the 1980s (See Appendix Table A-2).

During the second period also, the export price index of selected agricultural commodities was significant at the .10 level in model II. However, the index was not statistically significant in models I and III. Estimated coefficients ranging from 1.18 to 1.87 suggest a positive relationship between increasing export price of agricultural crops producible on forestlands and a government's willingness to allow greater forest harvesting.

The coefficient on population, the variable most generally blamed for forest depletion, was statistically non-zero in models I and III only at the .10 significance level. The positive coefficient on population indicates, as expected, that a larger population was associated with greater logging and degradation of tropical forests.

During the second period, over 1900 additional hectares of forests were logged and, thus, degraded, for every additional million people. In all other periods, however, population was not a statistically significant explanatory variable in the three models.

Period 3. In period 3, results show the real rate of devaluation of the domestic currency relative to the US dollar to be the most statistically significant variable explaining logging-related forest depletion in tropical countries. The real devaluation rate was significant at the .01 level in models I and II and at the .10 level in model III.

In model III, however, the interaction between real devaluation and the dummy variable for high indebtedness was also significant at the .01 level. These results indicate that during the third period when the IMF required currency reform as a precondition for further borrowing, forest depletion in highly indebted countries was much more responsive to currency fluctuations than in non-highly indebted countries.

Estimates from models I and II suggest that as a group, tropical developing countries logged from 84 to 94 thousand hectares of closed broadleaved forests for every percentage point real devaluation of their currencies relative to the US dollar. Estimates from model III indicate that each percentage point real devaluation of the domestic currency was associated with additional forest depletion of 48 thousand hectares in non-highly indebted countries and of 99 thousand hectares in highly indebted countries.

The domestic cereal production ratio continued to be statistically significant in all three models during the third period. The estimated coefficient of the domestic cereal production ratio in each model was positive and significant at the .05 level. Coefficient estimates indicate that every percentage point increase in the proportion of domestically produced cereals out of total cereal consumption during the third period was associated with the harvest of an additional 20 to 25 thousand hectares of tropical broadleaved forests. These figures are higher than the estimates for the previous period.

Per capita real income also remained statistically significant in period 3. The coefficient of per capita income was significantly positive at the .05 level in model I and at the .10 level in models II and III. Each additional real dollar increase in per capita income was associated with additional logging of about 320 to 450 hectares.

The coefficient on the debt service ratio was statistically non-zero with a .05 level of significance in model III. Just as in period 2, the debt service ratio was negatively related to industrial logging during the third period. Every percentage point increase in the ratio was associated with a decline ranging from 26 to 51 thousand hectares in the area of forest logged.

Likewise, during the third period, the coefficient of the export value index of tropical wood was consistently negative in the three models. It was statistically significant at the .10 level in model II and was almost significant in model III.

The negative coefficient on the index suggests greater forest harvesting where the export value of tropical wood was lower. This seems to imply that tropical countries tended to make up for lost revenue from lower value by increasing the volume of wood sold.

Indeed, the coefficient estimates indicate that each point increase in the export value index of tropical logs was associated with a decrease of from 8 to 12 thousand hectares in the forest area logged.

Undoubtedly, there had been a fundamental change from period 1 when high export value of tropical wood was highly positively correlated with wood harvesting and forest degradation. The log export ban and other restrictions on forest harvest and conversion many governments started putting in place in the mid-1970s may have helped temper the response to attractive export prices of tropical wood during this period.

Period 4. In period 4, the ratio of arable land to agricultural population and the real devaluation rate were the only statistically significant explanatory variables. Both had positive coefficients.

The arable land ratio was significant at the .01 level in model I and at the .05 level in models II and III. Coefficient estimates indicate that a unit increase in the arable land to rural population ratio was associated with about 1.8 to 2.5 million more hectares of closed broadleaved forests degraded.

The coefficient of real devaluation was significant at the .05 level in model I and at the .10 level in model II. Neither the real devaluation rate nor the devaluation-indebtedness interaction was statistically significant in model III.

The estimated coefficients of the real devaluation rate in models I and II were considerably less than those of the previous period. Still, every percentage point decrease in the real value of the domestic currency relative to the US dollar was associated with about 15 thousand additional hectares of forests destroyed by logging. Considering the massive devaluations during this period's debt crisis, indeed, the resulting total forest destruction due to currency adjustments was alarmingly high.

Tropical Deforestation, 1976-80

The availability of data on average annual tropical deforestation for the period 1976-80 provided an excellent opportunity to check whether the macroeconomic variables significantly associated with industrial logging of closed broadleaved forests in period 3 were also significantly associated with deforestation. Models I, II, and III were estimated using the FAO/UNEP (1981b-1981d) data on average annual deforestation, in 1000 hectares, as the dependent variable.

The coefficient estimates from the deforestation regressions are presented in Table 5-10. Since forest degradation due to logging and deforestation, although highly correlated, are not the same, the coefficient estimates reported in the tables are not directly comparable to those reported for period 3 in Tables 5-7 to 5-9.

Among the three models, model II had the highest explanatory power and model I, the lowest, with R-squares of .81 and .54, respectively. Condition numbers showed no significant collinearity and White's test revealed no significant inconsistency in the covariance matrix.

F-tests rejected at the .01 significance level the parameter restrictions implied by specifying model I against II and model I against III. The calculated F-statistics were F(6,30)=7.12 and F(1,35)=21.20, respectively.

Analysis of covariance results show a statistically significant difference in the magnitude of deforestation between highly indebted and non-highly indebted countries (Table 5-11). As a group, highly indebted countries deforested over 200,000 more hectares than non-highly indebted countries, all other things constant.

This difference in the magnitude of deforestation among countries of different credit standing was not reflected by a corresponding significant coefficient on the dummy variable for credit category in the model II logging regression for the third period. Based on this observation,

Table 5-10. Coefficient estimates from regressions of deforestation, 1976-80 (numbers in parenthesis are standard errors).

Variable	Model I	Model II	Model III
Region 1[a]		91.73	
		(71.65)	
Region 2[a]		215.18	
		(91.70)	
Region 3[a]		-26.85	
		(76.25)	
Income Group 1[a]		-112.57	
		(83.48)	
Income Group 2[a]		-63.72	
		(68.42)	
Debt Group 1[a]		212.86***	
		(69.06)	
Constant	-414.33**	-247.36	284.49
	(173.90)	(157.82)	(142.01)
Per Capita Income	0.09**	0.07**	0.07**
	(0.03)	(0.03)	(0.03)
Log Export Value Index	-1.39	-3.04***	-1.46
	(0.92)	(0.76)	(0.74)
Agric. Export Price Index	-0.25	-0.11	0.37
	(0.67)	(0.52)	(0.55)
Debt Service Ratio	-0.30	-8.76**	-6.39
	(4.26)	(3.50)	(3.66)
Real Devaluation Rate	13.30***	18.57***	4.57
	(4.37)	(3.46)	(3.98)
Dom. Cereal Prodn. Ratio	5.02***	5.87***	4.51***
	(1.68)	(1.27)	(1.35)
Population	0.34	0.09	0.11
	(0.30)	(0.26)	(0.24)
Arable Land per Ag. Capita	71.85	-27.77	42.07
	(115.75)	(89.38)	(92.87)
Debt Group 1* Devaluation[b]			12.42
			(2.70)
R-square	0.54	0.81	0.71
Adj. R-square	0.44	0.72	0.64
F-Ratio	5.26***	9.16***	9.65***

* Significant at 0.10 level.
** Significant at 0.05 level.
***Significant at 0.01 level.

[a] Dummy variable
[b] Interaction variable

Table 5-11. F-ratios from analysis of covariance of tropical deforestation, 1976-1980.

Source	F-ratio	Degree of Freedom
Region	2.25	3
Income Group	0.92	2
Credit Status	9.50***	1
Per Capita Income	7.24**	1
Log Export Value Index	15.93***	1
Agric. Export Price Index	0.05	1
Debt Service Ratio	6.27**	1
Real Devaluation Rate	28.75***	1
Domestic Cereal Prod. Ratio	21.40***	1
Population	0.12	1
Arable Land per Ag. Capita	0.10	1
Error Sum of Squares	513165.64	
Degrees of Freedom	30	

* significant at 0.10 level [a]Dummy variable
** significant at 0.05 level
*** significant at 0.01 level

it could be surmised that logging as an indicator of deforestation was not sensitive to intercept shifts across groups of countries.

The regression coefficient estimates of model II also indicated higher deforestation in South America, primarily due to deforestation in the Brazilian Amazon. The dummy variable for South America, however, was statistically significant only at the .1 level. Furthermore, analysis of covariance results showed that despite the significant coefficient of the dummy variable for this one region, there were no statistically significant differences in deforestation across regions.

Just as in the logging regressions, the constant terms in the three models were negative. In model I, the constant term was statistically significant at the .05 level while in models II and III, the constant term was not significantly different from zero.

Regression results reveal that tropical deforestation was significantly related with the same variables that were statistically associated with industrial logging in period 3. Deforestation increased with real domestic currency devaluation, greater domestic production of cereal grains, increasing per capita real income, and falling international prices of tropical wood. Higher debt service ratios were associated with lower deforestation.

Real currency devaluation was significant at the .01 level in models I and II but was not significant in model III. However, in model III, the interaction between real devaluation and the dummy variable for high indebtedness was statistically significant at the .01 level, indicating that in highly indebted countries, currency devaluation brought about greater deforestation.

From 13.3 to 18.6 thousand hectares of closed broadleaved forests were deforested in tropical countries as a group for every percentage point drop in the real value of their domestic currencies relative to the US dollar. Coefficients from model III indicate that highly indebted countries deforested about 12.4 thousand more hectares than non-highly indebted countries for every percentage point real devaluation of their domestic currencies.

The domestic cereal production ratio was significant at the .01 level in the three models. Per capita income was statistically significant only in models I and III while the unit export value index of tropical logs was significant only in model II.

About 45 thousand additional hectares were deforested for every percentage point increase in the domestic cereal production ratio. Only 70 to 85 additional hectares of closed broadleaved forests were deforested for every dollar increase in the real per capita income.

According to model II estimates, every point drop in the export value index of tropical logs was associated with deforestation of an additional 3 thousand hectares of tropical forests. This result is consistent with findings from the logging regressions indicating that industrial logging was negatively related to the export value index of tropical logs.

Based on these results, it seems that higher world prices of tropical wood along with some institutional controls on log exports may have helped reduce forest disturbance during the third period.

The negative sign on the coefficient on the debt service ratio echoes the results obtained from the logging regressions throughout the 1970s. The debt service ratio was statistically significant at the .05 level in model II where its estimated coefficient was -8.76. In models I and III, however, the debt service ratio was not a significant explanatory variable.

It appears that during the third period, tropical deforestation was somewhat alleviated by foreign loans still pouring in, albiet, on conditions imposed by the IMF. According to the results of model II, it seems that tropical developing countries did not have to mine their forests as extensively in order to raise the financial resources the international community provided.

Elasticity of Tropical Forest Depletion

The impact of statistically significant variables on tropical forest depletion can be more readily appreciated by examining the elasticities calculated from their regression slope coefficients. In the following sections, the elasticity of the forest depletion indicators with respect to the significant explanatory variables are presented and interpreted.

The elasticities reported in Table 5-12 measure the percent change in the area of tropical closed broadleaved forests industrially logged, and thus, degraded, with every percent change in an explanatory variable[6]. They indicate the average responsiveness of the magnitude of tropical forest degradation to changes in significant macroeconomic variables over the time period considered. Forest degradation is said to be elastic, inelastic or unit elastic with respect to an explanatory variable if the absolute value of the calculated elasticity is greater than, less than, or equal to unity.

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[6] The elasticity of a variable Y with respect to a variable X is defined as: $\varepsilon_{YX} = (\delta Y/\delta X) * (X/Y)$.

Table 5-12. Elasticity of tropical forest degradation with respect to significant variables.

Variable	Model 1	Model 2	Model 3
Period 1			
Log Export Value Index	1.47***	1.57**	1.53**
Period 2			
Per Capita Income	2.37***	2.41***	2.25***
Agric. Export Price Index	0.80	1.04*	0.81
Debt Service Ratio	-1.19*	-1.51**	-1.22*
Dom. Ceral Prodn. Ratio	5.12***	4.75***	5.04***
Population	0.25*	0.23	0.22*
Period 3			
Per Capita Income	1.56*	1.75*	1.23*
Log Export Value Index	-3.02	-4.43*	-3.13
Debt Service Ratio	-0.86	-1.46	-1.72**
Real Devaluation Rate	4.12***	4.61***	
Non-highly indebted			2.36*
Highly indebted			3.43***
Dom. Cereal Prodn. Ratio	5.22**	6.01**	4.71**
Period 4			
Real Devaluation Rate	1.39**	1.40*	0.70
Arable Land Per Ag. Capita	3.71***	4.00**	2.83**

* Significant at 0.10 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

Since logging and deforestation are highly correlated, the forest degradation elasticities provide indirect measures of the influence of macroeconomic factors on tropical deforestation.

Period 1

During the first period, the export value of tropical wood seems to have been the major factor encouraging industrial logging of closed broadleaved forests. Every percent increase in the unit export value index of tropical logs was associated with approximately 1.5 to 1.6% increase in the area of forest degraded by logging.

However, as discussed above, the influence of the export value of tropical wood may have been confounded by the effects of income and agricultural export prices which tended to move in the same direction during this period of relatively stable prices. Nevertheless, the results do indicate that industrial logging and associated tropical forest destruction during this period were apparently linked to economic incentives particularly in the export market.

Period 2

The international grain shortage of the early 1970s clearly had a significant and adverse impact on tropical forests. Forests were depleted as countries sought greater food self-sufficiency, particularly in cereals. The area of closed broadleaved forests logged increased by 4.8 to 5.1% for every percent increase in a country's domestic cereal production ratio.

Per capita real income was another highly statistically significant explanatory variable in this period. Forest degradation associated with logging was very income-elastic. The area of closed broadleaved forest logged increased by about 2.3 to 2.4% for every percent increase in per capita real income.

The positive sign of the income coefficient suggests that the depletion of tropical forests can not simply be attributed to poverty. While poverty may be an important driving force in the later stages of deforestation when logged-over forests are cleared for subsistence agriculture, the initial impetus for logging was unambiguously linked to increasing income.

During the first half of the 1970s, average export price of major agricultural crops increased for 60% of the countries in the study. This increased incentive for agricultural export crop production seems to also have contributed to the willingness of governments to allow greater forest harvesting during this period. Forest degradation was almost unit elastic with respect to the agricultural export price index.

Contrary to expectation, in all three models, the debt service ratio was negatively associated with forest degradation. Elasticity with respect to the debt service ratio ranged from -1.2 to -1.5. These negative elasticities suggest that the ready availability of international credit during the second period may have eased the financial pressure on tropical developing countries, alleviating the need to liquidate forest resource stocks.

Among the statistically significant explanatory variables in period 2, population had the smallest direct impact on the magnitude of closed broadleaved forests degraded by logging. Forest degradation was population-inelastic. Elasticity of tropical forest degradation with respect to population was around 0.25.

Period 3

Logging elasticities. Real exchange rate devaluation had the strongest statistical relationship to logging-related forest depletion in period 3. The estimates indicate that the extent of industrial logging and associated damage to tropical forests were very sensitive to movements in the real exchange rate.

According to models I and II, the area of closed broadleaved forest logged in tropical developing countries as a group increased over 4% with every percent real devaluation of the domestic currency relative to the US dollar. Estimates from model III placed the elasticity with respect to real devaluation to be around 3.4 in highly indebted countries and only 2.4 in non-highly indebted countries.

These results suggest, rather strongly, that exchange rate adjustments required of borrower countries by the IMF-

World Bank group as a precondition for further borrowing may have led tropical developing countries to mine and liquidate their forest stock. These findings also indicate a strong linkage between fluctuations in currency values, which for many developing countries are externally induced, and forest resource degradation.

The effort towards greater food self-sufficiency continued to deplete tropical forests during the third period. The elasticity of forest degradation with respect to the domestic cereal production ratio ranged from 4.7 to 6.0.

The area of closed broadleaved forests logged also remained very elastic with respect to real per capita income. The elasticity of forest degradation with respect to income ranged from 1.4 to 1.8 during this period. Just as in the second period, forest degradation increased with increasing per capita real income.

Likewise, just as in the second period, logging-related forest degradation apparently decreased with inceasing debt service ratio. The estimate from model III indicates the elasticity with respect to the debt service ratio to be as much as -1.72.

Forest degradation during the third period also seemed highly and negatively responsive to export value of tropical logs. Elasticity of forest degradation with respect to the unit export value index of tropical logs was -4.4. Again, it should be pointed out that this negative relationship may partly reflect the effects of a ban on export of unprocessed logs in major producing countries.

Deforestation elasticities. The nature of the macroeconomic-tropical deforestation linkage during the third period, the only period for which deforestation data was available, can also be examined using the elasticities calculated from significant regression coefficients. The deforestation elasticities are reported in Table 5-13.

Table 5-13. Elasticity of tropical deforestation with respect to significant variables, 1976-80.

Variable	Model I	Model II	Model III
Per Capita Income	0.75^{**}	0.61^{**}	0.57^{**}
Log Export Value Index	-1.18	-2.57^{***}	-1.24
Debt Service Ratio	-0.02	-0.68^{**}	-0.49
Real Devaluation	1.47^{***}	2.05^{***}	
Non-highly indebted			0.50
Highly indebted			1.08^{***}
Dom. Cereal Prodn. Ratio	2.74^{***}	3.20^{***}	2.46^{**}

* Significant at 0.1 level.
** Significant at 0.05 level.
*** Significant at 0.01 level.

Note that these elasticities are not directly comparable to the forest degradation elasticities for period 3 in Table 5-12. The elasticities below measure the impact of significant macroeconomic factors on the extent of deforestation while those above measure their impact on the extent of forest degradation associated with industrial logging. The difference between the two sets of elasticities goes back to the distinction discussed in chapter 1 between forest degradation and deforestation, i.e., between qualitative and quantitative forest depletion.

Since not all logged-over forests are actually deforested, deforestation was expected to be less responsive to changes in the economic variables. Therefore, the deforestation elasticities were expected to be lower than the elasticities of logging-related forest degradation. Examination of the two sets of elasticities confirm this expectation.

Increasing reliance on domestically produced cereal grains had the largest impact on tropical deforestation during the 1976-1980 period. The area deforested increased from 2.5 to 3.2% with every percent increase in the domestic cereal production ratio. This finding validates the conclusion drawn from the forest degradation elasticities, namely, that there was pronounced conflict between food production and tropical forest preservation.

Tropical deforestation was also closely related to real devaluations during the third period. According to estimates from models I and II, the elasticity of deforestation with respect to the real rate of domestic currency devaluation relative to the US dollar ranged from 1.5 to 2.1 in tropical countries as a group.

However, estimates from model III were a little more conservative. Deforestation elasticities were lower when the countries' credit status was taken into consideration. Among non-highly indebted countries, elasticity of deforestation with respect to real devaluation was only 0.5.

In highly indebted countries, the elasticity was 1.08, indicating that deforestation was almost unit elastic with respect to real devaluations. The area deforested increased slightly more than proportionally to the rate of real currency devaluation relative to the US dollar.

On the other hand, increasing world price for tropical wood seemed to decrease deforestation. According to estimates from model II, for every percent increase in the world price of tropical wood, the area of closed broadleaved forests deforested decreased by as much as 2.5%.

Deforestation also appeared to decreased with increasing debt service. Elasticity with respect to the debt service ratio ranged from -0.4 to -0.7.

While logging-related tropical forest degradation was income elastic, deforestation was income inelastic during the third period. Every percent increase in real per capita income was associated with only 0.4 to 0.7% increase in the area deforested. Therefore, while increasing income encouraged greater deforestation, the increase in the area deforested was proportionally less than the increase in per capita real income.

With the benefit of hindsight, it seems that tropical deforestation during the third period might have been significantly reduced by conditions more favorable to developing countries in the world markets for tropical wood, cereal grains and development finance. Although the resulting prosperity and income increase from such rosy scenario would have generated pressure for forest clearing and conversion to more profitable land uses, they would also have created productive opportunities outside the forest. On balance, more forests might have been preserved.

Period 4

In the 1980s, per capita real income dropped dramatically in almost all countries included in the study. Per capita income was no longer a statistically significant variable explaining forest degradation in period 4 (Return to Table 5-12). It seems that the direct effect of income on forest degradation was not symmetrical. Logging and associated forest degradation increased during periods of rising income but did not drop correspondingly when income fell.

By the fourth period also, the domestic cereal production ratio no longer had a statistically significant direct relationship with forest degradation. Recall that developing countries had begun questioning the effectiveness of food self-sufficiency as a policy objective during this period.

Instead, the ratio of arable lands to rural population had the strongest influence on tropical forest degradation. Every percent increase in the arable land ratio was associated with approximately 3 to 4% increase in the area of closed broadleaved forests harvested.

The figures imply considerable agricultural expansion into forested zones. It is not clear from the data whether the expansion was for subsistence or for export agriculture. Nevertheless, the results imply that as living standards dropped and as commodity export prices tumbled, developing countries fell back on agriculture at the expense of the forest.

Estimates from models I and II showed that real exchange rate devaluations continued to have significant influence on tropical forest depletion during the fourth period. Logging-related forest degradation remained elastic with respect to real currency devaluations with elasticity of 1.4.

The elasticity of tropical forest degradation with respect to real currency devaluations during the fourth period was lower compared to that of the previous period. This may have been due to reduction in the stock of readily exploitable forests as well as capital constraints which slowed down industrial wood harvesting in many countries.

CHAPTER 6
CONCLUSION

This study looked back to the years 1967 to 1985 and saw a little more clearly how the interplay of economic and political factors at the global and national levels affected forests in 45 tropical developing countries.

It was argued that political and economic pressures on governments during the study period affected forestland allocation decisions by affecting perceived relative costs and benefits of forest harvesting, conservation, and conversion to alternative land uses.

Since logging often constituted the first step towards deforestation, the area of closed broadleaved forests industrially logged was used as the measure of forest degradation and indicator of deforestation. This measure was also interpreted as a reflection of governments' forest allocation decisions.

Although the quality of the raw data used in the study makes it very difficult to draw firm conclusions, available evidence supports the contention that the destruction of tropical forests during the years covered by the study was more than a question of population pressure on land resources. Results indicated that compared to the macroeconomic driving forces, population size had a relatively small direct impact on the magnitude of forest depletion. Clearly, a simple Malthusian explanation for the depletion of tropical forests is inadequate.

Statistical tests indicated that during the study period, the magnitude of industrial logging, and by implication, the forest degradation associated with it, did not significantly vary by geographic region, income group and international indebtedness.

Tests using available data on deforestation for 1976-1980 indicated, however, that deforestation was greater in highly indebted countries compared to non-highly indebted countries. The fact that this difference was not reflected by a corresponding difference in the extent of logging in the two groups of countries during the same period demonstrated that industrial logging was less than perfect as an indicator of deforestation.

Underreported figures for industrial wood extraction from which forest degradation was calculated and low estimates of deforestation make this study's coefficient and elasticity estimates very conservative. Nevertheless, even these conservative figures suggest an alarmingly high responsiveness of the magnitude of tropical forest depletion to the macroeconomic variables considered in this study.

While externally-mediated factors such as international credit, income, export prices, and currency values played a major role, domestic factors such as arable land availability and response to the problem of food security were important variables explaining forest depletion during the study period.

Agricultural Expansion and Forest Depletion

There is no question about the existence of a conflict between food production and forest preservation in tropical developing countries. Deteriorating domestic currency values apparently heightened this conflict particularly starting the second half of the 1970s.

Results suggest considerable agricultural expansion into forested zones during the study period. The strong positive relationship between increased domestic production of cereal grains and the size of tropical forests degraded or destroyed during the 1970s supports this conclusion. The strong positive relationship between forest depletion and increasing arable land per agricultural capita during the fourth period bolsters this contention.

The expansion of agriculture into forestlands is particularly interesting given leaps in agricultural technology during the study period which made it possible to more intensively use existing agricultural lands. It appears that technological change in agriculture did not prevent tropical forests from going the same way that temperate forests went centuries before.

In this regard, developing countries are not much different from now developed countries which also destroyed significant areas of forest in the course of their economic growth and development. Unfortunately, the ecological importance of tropical forests, the current sad state of the world environment, a much larger global population and abject poverty in developing countries dependent on forest resources make the consequences of tropical forest depletion much more severe.

Export Prices and Forest Depletion

As expected, higher export price of major agricultural crops was associated with greater forest depletion. The statistical relationship between agricultural export price and forest depletion, however, was significant only during the early 1970s coinciding with the brief boom in prices of major agricultural commodities.

Forest depletion exhibited unit elasticity with respect to the agricultural export price index during this period. During the rest of the study period, however, the export price of major agricultural crops did not seem to markedly affect the extent of forest degradation.

On the other hand, forest degradation and the value of tropical wood in the export market appears to have undergone structural change during the study period. In the late 1960s, higher tropical wood value was associated with greater forest depletion. The opposite was observed by the late 1970s, however, when a number of countries started imposing a ban on the export of unprocessed logs, the form in which the bulk of tropical wood is exported. Industrial logging and deforestation were then both negatively related with the export value index of tropical logs.

If this negative relationship still holds, more favorable prices for tropical wood exports might help rather than hurt the cause of tropical forest conservation. This observation is supported by evidence indicating that during the 1980s, developing countries made up for depressed prices by increasing the volume of wood harvested and sold.

If indeed deforestation tends to be less when the export price of tropical wood is high, international agreement to raise the price of tropical wood by incorporating the cost of deforestation externalities may be a mechanism for encouraging tropical forest conservation. Expectation of higher value of future forestry output may persuade governments to postpone harvesting and conversion of natural tropical forests. Of course, mechanisms for more effective enforcement of forestry regulations have to be developed at the same time.

Income and Forest Depletion

The positive relationship between per capita real income and tropical forest depletion in the 1970s, years of generally increasing income, suggests that the increased effective demand created by higher income had the net effect of increasing the opportunity cost of keeping land under forest cover. Increased demand for forestry and agricultural products apparently encouraged tree harvesting and made agricultural land rents seem potentially much higher than returns from forestry.

Developing countries are obviously still at the range of income where environmental quality is only secondary to other more basic needs. Thus, during the study period, higher income brought about greater forest destruction rather than conservation. If this relationship between income and forest depletion continues into the future, the commonly proposed solution to environmental degradation in poor countries, i.e., increasing income via higher levels of economic development, may lead to faster rather than slower forest depletion.

Interestingly enough, the reduction in income during the 1980s was not associated with a corresponding significant decline in forest depletion. It is suspected that skewed income distribution amplified the consumption effects of income increase. Unfortunately, it was not possible to pursue this question further since data on income distribution during the study period were available for only a very few countries.

Nevertheless, one can argue that an increasing but unequally distributed income can encourage greater production of agricultural home goods since the marginal propensity to spend additional income on these goods tends to be high among low income classes. With majority of the population in tropical developing countries belonging to the low income classes, even small increases in income could significantly increase the derived demand for agricultural land. Where lands are inadequate or unavailable, this increased demand could easily invite forest clearing. Indeed, results during the second and third periods tend to support this interpretation.

Debt, Devaluation, and Forest Depletion

While highly indebted countries deforested larger areas of tropical forests compared to non-highly indebted countries during 1976-1980, the only period for which deforestation data were available, higher debt service did not translate into greater deforestation. In fact, the consistently negative coefficient on the debt service ratio suggests that forest destruction tended to be less in countries in which a higher proportion of export earnings went to service international debt.

This seemingly counter-intuitive connection between debt service and tropical forest destruction definitely needs more detailed study. However, based on the findings of this study, it appears that as long as foreign capital continued to be accessible, higher debt service was not incompatible with some degree of forest preservation. It seems that externally provided capital helped spare tropical forests from being converted into financial assets. If so, resumption of capital flows to developing regions might help save tropical forests.

It seems that currency devaluations, rather than debt service, encouraged tropical developing countries to exploit, and in the process destroy, their forest resource base. Coefficient estimates show strong links between real domestic currency devaluation and forest depletion during the decade from 1976 to 1985.

During the second half of the 1970s when conditionality measures were first imposed by international lending institutions, the influence of real exchange rate devaluation on both industrial logging and deforestation were significantly higher in highly indebted countries compared to non-highly indebted countries. Larger areas of forests were logged and destroyed in highly indebted countries for every percentage point drop in the real value of the domestic currency relative to the US dollar.

These findings lend empirical support to the suspicion that foreign exchange difficulties may have been responsible for high rates of tropical forest destruction. Since the foreign exchange shortage tended to be much more acute in highly indebted countries, larger areas of natural tropical forests were liquidated by this group of countries.

As a tool for economic adjustment, currency devaluation has proven very effective: successive devaluations have reduced import demands and have brought domestic resources into production activities. Unfortunately, tropical forests have not been spared from this resource mobilization.

The connection between domestic currency devaluation and tropical deforestation suggests the need for serious reexamination of the IMF-World Bank policy requiring strict adherence to structural adjustment programs centered on currency devaluation. Such reexamination seems to be warranted not only in consideration of their harsh socio-economic and political consequences, as many critics have charged, but also on environmental grounds.

The specter of substantial global externalities arising from the irrevocable destruction of natural tropical forests provides further justification for rethinking economic policies. Economic measures customarily thought of as being simply fiscal or monetary instruments for attaining desired economic goals have been shown to have significant, often unforeseen and unintended, environmental consequences.

This reality should be given the weighty consideration it deserves in the design of economic policies everywhere. It is especially important in the developing world where the well-being and survival of nations depend on the integrity of their natural resource base.

There is no question about the need for developing countries to exercise greater control and to strike a balance between protection and judicious use of their natural resources. However, great responsibility remains on the shoulders of international development institutions and policy-makers in developed countries. Their dominant role in the global economic system makes their policy decisions especially important. Effects of their policies are felt in the deepest and farthest corners of tropical forests around the world.

Epilogue

The world has not stood still since 1985, the last year considered in this study. In general, developing countries today find themselves in even more difficult straits. In highly indebted countries especially, currency devaluations, inflation rates in the thousand percent range and massive unemployment have become standard fare. As a result, the very fabric of societies and their people's fate in the economic and political process has been severely eroded.

Standards of living and per capita incomes in many countries continue to spiral downward. Exports have not provided a way out as markets in developed countries remain closed and heavily protected. The collapse of communism in eastern European countries and their heavy demand for capital for economic restructuring pose a stiff competition for shrinking development finance.

More recently, the Iraqi invasion of Kuwait, the sharp increases in oil prices and the stagflation that is expected to follow could make an already extremely difficult situation worse for oil-importing countries where oil remains a major item in the total import bill. For oil-exporting countries, however, higher oil prices could be a welcome relief.

The suggestion of structural change over time in the relationship between forest depletion and the macroeconomic factors considered in the study makes it difficult to extrapolate from the results. It is even more difficult to chart a path away from tropical forest destruction given the current state of affairs in the world economy and in the economies of developing countries.

Although environmental issues have moved to the forefront of political debate and cries for forest and natural resource conservation are heard the world over, in developing countries, the objective conditions encouraging resource depletion have not significantly changed. Forests and other resources continue to be mined and liquidated to meet food, financial and other needs.

A glimmer of hope in the continuing rise in oil prices is the increased likelihood that the efforts to develop alternative energy sources will be sustained and pursued more seriously by countries with the technical and financial capability to do so. Developing countries desperately need affordable, clean energy that is compatible with their resource endowments. The foreign exchange savings such technology would make possible could finance development and provide countries the option of importing food instead of having to grow them on forest soils of only marginal fertility.

Another positive note is the increased international effort at monitoring and generating timely information on the state of the world's tropical forests. This improvement in data availability and quality would certainly help future research understand and clarify details of the relationships suggested by the results of this study.

Finally, there are various initiative by both government and non-government organizations to protect and conserve remaining tropical forests and species found therein. Some initiatives, such as the debt-for-nature swap, offer a creative approach to the twin problems of deforestation and international debt.

Although these various efforts remain puny in comparison to the severity of the deforestation problem, at least, positive steps are being attempted. Whether or not these initiatives succeed still remains to be seen.

APPENDIX
DATA TABLES

Table 1. Average annual deforestation of closed broadleaved forests, 1976-80 (in 1000 hecatares).

Country	Annual Deforestation
Central America	
Costa Rica[2*]	60.00
Dominican Republic[2]	2.10
El Salvador[2]	4.00
Guatemala[2]	64.00
Haiti[1]	1.20
Honduras[2]	53.00
Jamaica[2*]	1.50
Mexico[3*]	420.00
Nicaragua[2]	97.00
Panama[2]	31.00
Trinindad & Tobago[3]	1.20
South America	
Bolivia[2*]	65.00
Brazil[2*]	1360.00
Colombia[2*]	800.00
Ecuador[3*]	300.00
Paraguay[2]	160.00
Peru[2*]	245.00
Venezuela[3*]	125.00
Asia	
Burma[1]	92.00
India[1*]	132.00
Indonesia[3*]	550.00
Malaysia[2*]	230.00
Philippines[2*]	100.00
Sri Lanka[1]	25.00
Thailand[2]	325.00

Table 1. continued.

Country	Annual Deforestation
Africa	
Burundi[1]	0.40
Cameroon[3]	80.00
Cent. African Rep.[1]	5.00
Ivory Coast[2*]	310.00
Ethiopia[1]	7.00
Gabon[3]	15.00
Gambia[1]	0.70
Ghana[1]	27.00
Kenya[1]	11.00
Liberia[2]	41.00
Madagascar[1]	165.00
Nigeria[3*]	285.00
Rwanda[1]	2.40
Sierra Leone[1]	5.80
Somalia[1]	3.00
Sudan[1]	5.00
Tanzania[1]	10.00
Togo[1]	2.00
Zaire[1]	165.00
Zambia[1]	40.00

Sources: FAO/UNEP. 1981b. Table 6a, p.64.
FAO/UNEP. 1981c. Table 6d, p.82.
FAO/UNEP. 1981d. Table 6a, p.86.

Table 2. Closed broadleaved forest logged for industrial hardwood (in thousand hectares).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	28.41	45.85	57.20	31.36
Dominican Republic[2]	0.48	2.63	0.98	0.66
El Salvador[2]	7.90	7.88	8.46	10.06
Guatemala[2]	50.80	51.20	33.96	17.24
Haiti[1]	5.96	5.98	5.98	5.98
Honduras[2]	85.30	110.33	111.64	74.12
Jamaica[2*]	1.96	3.86	2.43	4.03
Mexico[3*]	374.18	452.31	482.02	524.58
Nicaragua[2]	42.86	78.50	88.00	88.00
Panama[2]	4.40	3.99	4.65	11.30
Trinindad & Tobago[3]	7.30	5.93	5.16	3.77
MEAN	55.41	69.86	72.77	70.10
C.V.	196.79	188.90	193.80	219.12
South America				
Bolivia[2*]	17.37	24.08	29.75	16.60
Brazil[2*]	4411.48	5149.95	9003.60	11515.68
Colombia[2*]	154.82	172.46	161.69	143.64
Ecuador[3*]	91.20	116.62	116.13	144.05
Paraguay[2]	83.08	96.65	159.98	654.32
Peru[2*]	69.98	112.58	149.73	114.38
Venezuela[3*]	45.87	57.75	57.82	57.82
MEAN	696.26	818.58	1382.67	1806.64
C.V.	235.37	233.39	243.07	237.27
Asia				
Burma[1]	171.16	159.25	160.12	199.41
India[1*]	305.47	437.48	526.94	600.10
Indonesia[3*]	379.04	845.08	898.79	941.16
Malaysia[2*]	308.92	344.56	447.26	473.17
Philippines[2*]	135.97	125.06	111.03	81.87
Sri Lanka[1]	7.83	8.32	9.38	11.42
Thailand[2]	180.60	211.45	211.99	168.67
MEAN	212.71	304.46	337.93	353.69
C.V.	59.51	91.06	91.14	94.42

Table 2. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	0.76	0.79	0.90	1.03
Cameroon[3]	190.47	237.00	338.10	411.17
Cent. African Rep.[1]	29.71	45.97	36.21	33.13
Ivory Coast[2*]	157.78	196.78	216.37	189.56
Ethiopia[1]	36.73	42.51	46.51	57.60
Gabon[3]	178.30	204.50	123.66	133.38
Gambia[1]	0.50	0.50	0.50	0.92
Ghana[1]	70.45	80.04	100.76	51.39
Kenya[1]	25.32	30.31	41.80	51.59
Liberia[2]	32.05	68.59	100.80	68.60
Madagascar[1]	50.62	22.38	29.57	33.49
Nigeria[3*]	80.96	99.31	157.19	217.74
Rwanda[1]	5.80	6.00	14.42	24.82
Sierra Leone[1]	17.13	16.53	20.18	18.03
Somalia[1]	1.72	2.04	2.31	2.43
Sudan[1]	75.76	89.82	97.93	115.16
Tanzania[1]	206.36	200.90	180.00	259.96
Togo[1]	9.54	12.38	11.70	14.90
Zaire[1]	122.37	85.48	100.07	158.07
Zambia[1]	76.72	87.85	123.52	92.16
MEAN	68.45	76.48	87.12	96.76
C.V.	98.76	99.46	99.83	109.68

Table 3. Unit value index of sawlog and veneer log export (1980 = 100).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	52.95	73.64	139.76	46.75
Dominican Republic[2]	180.97	123.61	132.87	105.53
El Salvador[2]	97.93	118.00	137.64	90.97
Guatemala[2]	110.62	107.44	132.30	96.41
Haiti[1]	84.68	99.46	130.66	97.62
Honduras[2]	71.41	71.61	84.31	33.26
Jamaica[2*]	183.82	155.40	160.42	83.33
Mexico[3*]	206.52	114.61	126.34	43.64
Nicaragua[2]	67.65	53.01	88.20	32.45
Panama[2]	83.24	83.71	76.92	53.82
Trinindad & Tobago[3]	200.79	166.63	171.05	89.56
MEAN	121.87	106.10	125.50	70.30
C.V.	48.22	32.95	24.20	40.18
South America				
Bolivia[2*]	123.45	108.38	142.49	22.90
Brazil[2*]	2638.21	795.27	267.47	43.62
Colombia[2*]	108.14	149.03	91.69	67.43
Ecuador[3*]	146.18	146.19	150.84	68.66
Paraguay[2]	123.74	128.86	150.82	81.86
Peru[2*]	1066.93	567.60	317.55	30.89
Venezuela[3*]	110.74	120.64	156.86	93.44
MEAN	616.77	287.99	182.53	58.40
C.V.	155.40	96.20	43.58	45.31
Asia				
Burma[1]	98.66	62.78	94.52	92.28
India[1*]	157.41	99.97	111.54	57.74
Indonesia[3*]	102.33	101.17	94.63	117.77
Malaysia[2*]	38.63	52.44	81.18	76.28
Philippines[2*]	71.35	60.53	83.14	53.24
Sri Lanka[1]	252.41	373.10	141.44	37.11
Thailand[2]	76.33	61.46	88.71	43.07
MEAN	113.87	115.92	99.31	68.21
C.V.	62.44	99.30	21.25	42.46

Table 3. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	64.03	99.13	90.09	59.26
Cameroon[3]	67.83	85.92	90.47	40.44
Cent. African Rep.[1]	28.35	57.86	82.64	63.24
Ivory Coast[2*]	70.54	99.27	85.99	51.86
Ethiopia[1]	30.70	56.15	70.59	60.37
Gabon[3]	64.84	101.56	68.97	54.24
Gambia[1]	53.91	80.58	74.38	49.38
Ghana[1]	479.58	681.93	279.94	17.72
Kenya[1]	56.18	71.46	86.78	104.02
Liberia[2]	55.77	78.19	79.27	80.30
Madagascar[1]	26.12	51.95	75.28	48.32
Nigeria[3*]	175.93	175.14	120.15	88.82
Rwanda[1]	52.01	73.29	78.48	52.80
Sierra Leone[1]	56.54	89.19	80.41	42.52
Somalia[1]	82.45	135.33	111.04	28.05
Sudan[1]	101.52	124.48	99.43	34.61
Tanzania[1]	135.50	93.01	81.56	41.96
Togo[1]	54.60	79.14	76.87	48.59
Zaire[1]	424.07	774.03	278.12	34.67
Zambia[1]	52.59	74.04	84.15	48.21
MEAN	106.65	154.08	104.73	52.47
C.V.	115.81	129.10	58.18	38.70

Table 4. Unit value index of selected agricultural exports (1980 = 100).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	103.59	86.84	193.82	18.81
Dominican Republic[2]	65.12	74.34	146.51	54.35
El Salvador[2]	46.97	55.67	96.25	29.58
Guatemala[2]	60.40	65.87	86.80	25.96
Haiti[1]	50.95	55.62	102.72	29.25
Honduras[2]	32.26	50.90	131.24	33.89
Jamaica[2*]	42.32	65.87	94.63	74.85
Mexico[3*]	111.75	114.85	155.82	23.87
Nicaragua[2]	83.85	84.28	155.71	21.91
Panama[2]	39.32	39.04	87.63	46.44
Trinindad & Tobago[3]	114.65	96.10	131.83	43.40
MEAN	68.29	71.76	125.72	36.57
C.V.	44.33	30.95	27.86	46.07
South America				
Bolivia[2*]	183.68	101.54	144.47	22.88
Brazil[2*]	885.57	505.10	341.51	10.38
Colombia[2*]	256.38	158.27	162.21	24.18
Ecuador[3*]	108.19	105.44	202.10	38.39
Paraguay[2]	56.59	64.84	150.53	26.52
Peru[2*]	401.21	235.94	251.32	14.75
Venezuela[3*]	68.85	85.04	141.43	51.21
MEAN	280.07	179.45	199.08	26.90
C.V.	104.63	86.11	37.28	51.85
Asia				
Burma[1]	51.51	59.76	70.85	43.95
India[1*]	92.00	64.52	112.07	73.13
Indonesia[3*]	175.31	109.35	147.46	44.92
Malaysia[2*]	60.11	68.03	89.27	66.84
Philippines[2*]	53.71	19.82	122.59	31.29
Sri Lanka[1]	142.76	127.75	127.17	68.77
Thailand[2]	62.36	59.68	78.82	51.61
MEAN	91.11	72.70	106.89	54.36
C.V.	53.98	48.94	26.26	28.63

Table 4. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	92.67	105.55	174.36	45.72
Cameroon[3]	69.74	71.43	109.00	37.11
Cent. African Rep.[1]	61.22	77.03	151.19	27.16
Ivory Coast[2*]	80.36	83.44	126.25	50.10
Ethiopia[1]	35.21	44.44	108.09	34.09
Gabon[3]	50.28	51.39	87.25	54.71
Gambia[1]	652.57	100.00	100.00	100.00
Ghana[1]	273.23	194.82	189.03	17.97
Kenya[1]	82.71	82.31	124.60	53.97
Liberia[2]	76.69	70.62	114.37	69.91
Madagascar[1]	59.89	58.36	109.56	22.74
Nigeria[3*]	236.41	127.98	125.60	154.34
Rwanda[1]	105.03	98.76	187.08	49.38
Sierra Leone[1]	72.62	78.66	131.11	40.75
Somalia[1]	176.82	162.10	141.88	54.71
Sudan[1]	178.21	466.06	284.13	40.85
Tanzania[1]	79.19	78.15	138.30	38.52
Togo[1]	70.35	64.57	117.74	43.64
Zaire[1]	484.75	553.95	399.72	23.27
Zambia[1]	317.00	489.34	268.36	110.08
MEAN	162.75	152.95	159.38	53.45
C.V.	99.32	101.89	48.23	62.20

Table 5. Per capita gross national product (in 1980 US$ per person)

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	1993.89	2050.35	2045.95	417.10
Dominican Republic[2]	736.74	945.58	1042.08	940.04
El Salvador[2]	736.80	778.80	823.04	592.22
Guatemala[2]	833.48	933.36	1091.47	993.47
Haiti[1]	212.72	215.43	260.59	263.04
Honduras[2]	607.11	602.11	632.71	599.21
Jamaica[2*]	4136.97	3279.16	1831.34	852.41
Mexico[3*]	3413.17	3958.25	2662.88	948.21
Nicaragua[2]	1476.92	1586.75	1293.25	552.65
Panama[2]	1359.63	1531.25	1585.28	1863.62
Trinindad & Tobago[3]	4419.78	5007.51	5515.61	4789.20
MEAN	1811.56	1898.96	1707.65	1164.65
C.V.	82.62	81.03	84.02	109.43
South America				
Bolivia[2*]	1597.37	1177.37	1165.40	244.62
Brazil[2*]	14881.86	10655.12	4244.25	252.57
Colombia[2*]	2449.86	1940.48	1422.26	764.36
Ecuador[3*]	1039.47	1182.29	1325.78	841.15
Paraguay[2]	747.19	942.69	1227.14	1177.65
Peru[2*]	6975.82	7386.00	2516.28	256.66
Venezuela[3*]	3320.10	3842.24	4157.20	2901.49
MEAN	4430.24	3875.17	2294.04	919.78
C.V.	114.34	97.22	60.18	102.80
Asia				
Burma[1]	184.53	160.52	149.28	148.76
India1[*]	214.87	210.35	218.03	200.10
Indonesia[3*]	594.47	498.44	543.46	391.81
Malaysia[2*]	740.65	1113.30	1463.11	1718.32
Philippines[2*]	830.74	637.18	693.85	476.80
Sri Lanka[1]	515.41	507.45	318.09	226.43
Thailand[2]	446.21	521.37	648.26	664.82
MEAN	503.84	521.23	576.30	546.72
C.V.	48.62	60.24	77.08	100.09

Table 5. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	196.02	217.06	219.74	197.58
Cameroon[3]	473.06	488.74	581.26	477.71
Cent. African Rep.[1]	259.53	278.90	337.45	195.63
Ivory Coast[2*]	922.77	1109.29	1268.08	634.27
Ethiopia[1]	104.76	129.06	108.78	103.35
Gabon[3]	2043.51	4533.57	6348.95	4114.00
Gambia[1]	291.92	384.10	358.27	233.25
Ghana[1]	4287.80	3843.68	2437.19	674.93
Kenya[1]	345.60	404.37	387.44	242.44
Liberia[2]	459.85	517.71	471.20	366.61
Madagascar[1]	354.02	373.23	350.26	160.83
Nigeria[3*]	1277.10	1225.50	1122.10	712.67
Rwanda[1]	184.31	168.04	237.85	229.94
Sierra Leone[1]	406.08	401.68	304.15	227.24
Somalia[1]	415.74	566.16	509.06	137.23
Sudan[1]	639.66	633.01	614.85	202.07
Tanzania[1]	268.99	285.02	303.45	192.18
Togo[1]	361.61	449.06	404.85	193.73
Zaire[1]	2676.12	1548.65	668.33	66.10
Zambia[1]	792.43	771.15	586.01	326.36
MEAN	838.04	916.40	880.96	484.41
C.V.	124.41	128.99	157.46	180.57

Table 6. Debt service to total export ratio (in per cent).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	10.84	10.10	16.26	28.12
Dominican Republic[2]	7.08	4.40	10.06	18.30
El Salvador[2]	3.50	5.50	3.70	14.58
Guatemala[2]	7.82	4.98	2.20	11.98
Haiti[1]	0.00	3.15	4.04	4.28
Honduras[2]	2.42	3.95	8.88	15.80
Jamaica[2*]	3.10	5.80	14.26	23.76
Mexico[3*]	24.54	23.10	44.62	34.84
Nicaragua[2]	9.60	12.85	12.25	19.65
Panama[2]	5.38	11.48	16.64	7.94
Trinindad & Tobago[3]	3.34	3.45	3.48	4.84
MEAN	7.06	8.07	12.40	16.74
C.V.	94.35	74.55	96.16	57.31
South America				
Bolivia[2*]	8.46	14.85	28.78	31.34
Brazil[2*]	15.86	14.80	28.20	31.04
Colombia[2*]	13.16	13.08	10.14	20.88
Ecuador[3*]	9.36	7.40	13.64	28.06
Paraguay[2]	10.24	9.95	8.32	10.38
Peru[2*]	14.28	25.10	28.20	24.66
Venezuela[3*]	2.24	4.52	8.24	14.02
MEAN	10.51	12.81	17.93	22.91
C.V.	43.21	51.89	55.49	35.94
Asia				
Burma[1]	13.38	16.58	18.14	34.05
India[1*]	26.08	18.58	9.44	10.41
Indonesia[3*]	6.16	6.30	11.98	13.30
Malaysia[2*]	2.44	2.70	5.50	8.92
Philippines[2*]	6.32	7.10	9.58	13.92
Sri Lanka[1]	7.92	15.08	10.86	10.66
Thailand[2]	3.64	2.45	3.76	10.38
MEAN	9.42	9.83	9.89	14.52
C.V.	86.44	68.87	47.14	60.54

Table 6. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	2.64	4.45	10.68	11.54
Cameroon[3]	3.64	5.68	7.47	10.73
Cent. African Rep.[1]	2.97	4.70	2.04	7.76
Ivory Coast[2*]	5.98	7.52	14.20	26.15
Ethiopia[1]	10.46	6.95	5.96	13.71
Gabon[3]	5.64	5.90	13.61	10.56
Gambia[1]	0.05	0.38	0.70	10.65
Ghana[1]	7.94	3.77	5.30	12.88
Kenya[1]	6.26	4.57	7.16	21.30
Liberia[2]	6.94	6.22	5.69	5.24
Madagascar[1]	4.40	3.85	6.23	24.79
Nigeria[3*]	4.68	2.23	1.68	17.84
Rwanda[1]	3.06	1.28	0.90	5.12
Sierra Leone[1]	7.74	8.92	15.98	12.07
Somalia[1]	2.02	3.55	3.00	19.52
Sudan[1]	8.34	14.70	9.88	13.10
Tanzania[1]	7.02	7.35	5.76	6.85
Togo[1]	2.90	5.67	14.98	17.77
Zaire[1]	3.56	10.08	10.56	18.58
Zambia[1]	4.42	14.30	19.68	14.88
MEAN	5.03	6.10	8.07	14.05
C.V.	50.74	61.16	67.61	42.88

Table 7. Average rate of change of real exchange rate relative to the US$ (in percent).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	3.18	19.35	9.05	55.96
Dominican Republic[2]	3.34	11.40	9.05	44.96
El Salvador[2]	3.34	11.40	9.05	2.86
Guatemala[2]	3.34	11.40	9.05	2.86
Haiti[1]	3.34	11.40	9.05	2.86
Honduras[2]	3.34	11.40	9.05	2.86
Jamaica[2*]	32.79	14.57	25.87	34.43
Mexico[3*]	3.34	11.39	24.60	71.26
Nicaragua[2]	3.24	11.51	18.04	31.23
Panama[2]	3.34	11.40	9.05	2.86
Trinindad & Tobago[3]	6.57	14.13	11.39	3.15
MEAN	6.29	12.67	13.02	23.21
C.V.	140.70	19.81	50.81	110.00
South America				
Bolivia[2*]	3.34	29.42	14.11	190.98
Brazil[2*]	24.54	29.34	69.90	191.26
Colombia[2*]	13.01	24.43	17.88	28.64
Ecuador[3*]	12.62	11.40	9.05	27.09
Paraguay[2]	3.35	11.39	9.05	18.44
Peru[2*]	9.97	12.74	62.30	115.64
Venezuela[3*]	3.46	10.08	9.08	17.21
MEAN	10.04	18.40	27.34	84.18
C.V.	76.99	48.45	97.92	95.79
Asia				
Burma[1]	3.59	20.75	9.62	8.04
India[1*]	2.75	14.39	7.85	12.57
Indonesia[3*]	28.18	12.90	20.03	15.73
Malaysia[2*]	3.26	5.06	7.03	5.67
Philippines[2*]	19.08	14.63	9.86	24.13
Sri Lanka[1]	9.52	16.26	32.79	13.87
Thailand[2]	3.34	10.81	9.16	8.92
MEAN	9.96	13.54	13.76	12.71
C.V.	100.11	35.80	68.63	48.36

Table 7. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	3.34	197.47	11.96	9.58
Cameroon[3]	6.48	5.10	8.84	20.00
Cent. African Rep.[1]	6.42	5.16	8.84	20.00
Ivory Coast[2*]	6.42	5.16	8.84	20.00
Ethiopia[1]	3.17	6.79	8.89	2.86
Gabon[3]	6.42	5.16	8.84	20.00
Gambia[1]	3.65	6.35	10.58	24.27
Ghana[1]	8.13	15.04	34.21	210.68
Kenya[1]	3.34	12.46	9.35	20.57
Liberia[2]	3.34	11.40	9.05	2.86
Madagascar[1]	6.42	5.16	8.84	29.51
Nigeria[3*]	3.16	35.85	6.44	13.52
Rwanda[1]	3.26	10.07	9.04	4.64
Sierra Leone[1]	7.08	13.89	12.78	41.55
Somalia[1]	3.34	8.01	9.05	52.83
Sudan[1]	3.32	11.40	17.73	42.70
Tanzania[1]	3.34	12.41	11.50	20.10
Togo[1]	6.42	5.16	8.84	20.00
Zaire[1]	3.34	11.40	60.43	109.03
Zambia[1]	3.34	8.58	13.55	32.65
MEAN	4.69	19.60	13.88	35.87
C.V.	37.33	216.46	89.63	131.93

Table 8. Domestic cereal production ratio (in percent).

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	63.12	61.88	76.84	71.86
Dominican Republic[2]	70.06	56.39	58.18	58.90
El Salvador[2]	93.25	88.67	85.05	77.11
Guatemala[2]	90.09	86.07	85.05	89.98
Haiti[1]	91.82	87.08	73.35	63.76
Honduras[2]	92.33	87.28	78.64	87.07
Jamaica[2*]	2.05	2.70	4.18	1.50
Mexico[3*]	106.16	84.63	84.44	82.03
Nicaragua[2]	90.06	87.33	81.70	78.00
Panama[2]	80.21	76.20	78.36	72.62
Trinindad & Tobago[3]	7.08	8.67	10.28	7.91
MEAN	71.48	66.08	65.10	62.80
C.V.	49.13	48.15	45.50	48.04
South America				
Bolivia[2*]	73.23	73.46	69.51	69.18
Brazil[2*]	94.67	93.39	87.60	87.52
Colombia[2*]	86.78	86.46	84.39	71.05
Ecuador[3*]	87.66	76.51	68.63	68.22
Paraguay[2]	80.70	85.31	91.85	93.07
Peru[2*]	66.94	56.87	55.93	58.58
Venezuela[3*]	51.64	43.57	47.59	36.48
MEAN	77.37	73.65	72.22	69.16
C.V.	18.97	24.06	23.05	27.01
Asia				
Burma[1]	107.37	103.40	105.68	104.84
India[1*]	95.27	96.54	99.12	99.06
Indonesia[3*]	95.75	93.30	91.01	95.34
Malaysia[2*]	85.17	73.53	61.63	53.76
Philippines[2*]	88.66	88.56	92.78	90.18
Sri Lanka[1]	59.18	58.70	63.45	76.55
Thailand[2]	122.92	125.85	131.13	142.43
MEAN	93.48	91.41	92.12	94.59
C.V.	21.11	23.45	26.25	28.71

Table 8. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	97.70	97.73	95.73	95.90
Cameroon[3]	90.91	90.13	87.47	87.64
Cent. African Rep.[1]	91.34	88.34	90.85	42.52
Ivory Coast[2*]	79.63	76.41	73.83	65.21
Ethiopia[1]	99.29	99.89	96.48	92.37
Gabon[3]	17.86	18.32	21.02	20.21
Gambia[1]	84.97	84.66	57.81	64.49
Ghana[1]	84.06	85.75	73.10	70.43
Kenya[1]	108.84	101.60	98.74	91.08
Liberia[2]	72.66	79.64	76.20	71.95
Madagascar[1]	100.12	96.20	93.96	89.54
Nigeria[3*]	96.90	95.96	86.03	83.25
Rwanda[1]	97.41	97.21	95.24	93.17
Sierra Leone[1]	88.79	92.17	91.53	88.13
Somalia[1]	72.71	55.34	66.16	51.08
Sudan[1]	95.73	96.64	96.01	87.35
Tanzania[1]	89.68	87.85	93.23	91.28
Togo[1]	95.19	93.61	90.50	81.94
Zaire[1]	79.24	69.89	66.04	74.82
Zambia[1]	94.14	86.23	83.08	79.68
MEAN	86.86	84.68	81.65	76.10
C.V.	21.58	22.70	22.82	25.70

Table 9. Arable land per agricultural capita (hectares per person)

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Central America				
Costa Rica[2*]	0.68	0.67	0.69	0.85
Dominican Republic[2]	0.36	0.36	0.41	0.45
El Salvador[2]	0.32	0.31	0.29	0.30
Guatemala[2]	0.55	0.53	0.48	0.44
Haiti[1]	0.28	0.28	0.27	0.27
Honduras[2]	0.56	0.60	0.79	0.71
Jamaica[2*]	0.44	0.49	0.56	0.36
Mexico[3*]	1.20	1.12	0.95	0.93
Nicaragua[2]	1.00	1.05	1.29	0.95
Panama[2]	0.91	0.84	0.86	0.90
Trinindad & Tobago[3]	0.71	0.77	0.86	1.06
MEAN	0.64	0.64	0.68	0.66
C.V.	46.74	44.61	46.00	45.00
South America				
Bolivia[2*]	0.98	1.42	1.23	1.18
Brazil[2*]	0.78	0.92	1.38	1.75
Colombia[2*]	0.71	0.73	0.76	0.76
Ecuador[3*]	1.26	1.12	0.74	0.72
Paraguay[2]	0.79	0.77	1.10	1.20
Peru[2*]	0.44	0.45	0.57	0.48
Venezuela[3*]	1.94	1.93	1.35	1.51
MEAN	0.99	1.05	1.02	1.09
C.V.	49.66	47.30	31.82	41.99
Asia				
Burma[1]	0.64	0.60	0.56	0.53
India[1*]	0.44	0.42	0.40	0.37
Indonesia[3*]	0.23	0.23	0.23	0.23
Malaysia[2*]	0.85	0.78	0.68	0.70
Philippines[2*]	0.50	0.49	0.46	0.45
Sri Lanka[1]	0.29	0.28	0.28	0.27
Thailand[2]	0.48	0.46	0.52	0.54
MEAN	0.49	0.46	0.45	0.44
C.V.	42.48	40.33	35.45	37.47

Table 9. continued.

Country	Period 1 1967-71	Period 2 1972-75	Period 3 1976-80	Period 4 1981-85
Africa				
Burundi[1]	0.39	0.39	0.38	0.34
Cameroon[3]	1.35	1.16	1.01	0.99
Cent. African Rep.[1]	3.90	2.76	0.98	1.00
Ivory Coast[2*]	2.14	1.48	0.62	0.57
Ethiopia[1]	0.65	0.62	0.49	0.40
Gabon[3]	0.38	0.51	1.05	1.02
Gambia[1]	0.96	0.78	0.48	0.36
Ghana[1]	0.53	0.50	0.48	0.42
Kenya[1]	0.19	0.18	0.19	0.16
Liberia[2]	0.40	0.37	0.30	0.26
Madagascar[1]	0.48	0.45	0.42	0.39
Nigeria[3*]	0.72	0.74	0.80	0.65
Rwanda[1]	0.21	0.23	0.23	0.22
Sierra Leone[1]	2.13	1.70	0.81	0.79
Somalia[1]	0.44	0.41	0.35	0.26
Sudan[1]	0.66	0.81	0.91	0.84
Tanzania[1]	1.07	0.85	0.37	0.33
Togo[1]	1.60	1.34	0.85	0.75
Zaire[1]	0.45	0.40	0.31	0.29
Zambia[1]	1.61	1.48	1.36	1.21
MEAN	1.01	0.86	0.62	0.56
C.V.	89.57	73.85	53.00	56.80

Table 10. Average population (1000 individuals).

Country	1967-71	1972-75	1976-80	1981-85
Central America				
Costa Rica^{2*}	1688.60	1914.75	2117.80	2374.21
Dominican Republic^{2}	4210.40	4873.50	5633.20	6404.46
El Salvador^{2}	3399.80	3925.25	4517.20	5236.77
Guatemala^{2}	5050.00	5902.50	6548.00	7530.00
Haiti^{1}	4168.00	4475.00	4836.00	5144.00
Honduras^{2}	2480.00	2947.50	3442.00	4094.00
Jamaica^{2*}	1857.80	1984.00	2121.40	2288.84
Mexico^{3*}	48778.60	56401.00	65474.20	76134.08
Nicaragua^{2}	1790.00	2047.50	2468.00	3062.00
Panama^{2}	1417.80	1609.50	1827.20	2058.34
Trinindad & Tobago^{3}	1024.00	1047.50	1058.00	1148.00
South America				
Bolivia^{2*}	4548.00	4737.50	5308.00	6088.00
Brazil^{2*}	92601.00	105209.25	118056.40	131206.23
Colombia^{2*}	20004.00	22657.50	24948.00	27516.00
Ecuador^{3*}	5776.00	6707.50	7674.00	8864.00
Paraguay^{2}	2242.00	2547.50	2960.00	3470.00
Peru^{2*}	12872.40	14680.00	16702.40	19176.75
Venezuela^{3*}	9952.00	11630.00	14070.00	16396.00
Asia				
Burma^{1}	27130.40	30159.75	33605.40	38003.86
India^{1*}	530713.60	591320.50	658026.40	725691.27
Indonesia^{3*}	116512.00	130527.50	139872.00	156514.00
Malaysia^{2*}	10178.00	11465.00	13000.00	14850.00
Philippines^{2*}	35792.00	40620.00	45828.00	52080.00
Sri Lanka^{1}	12214.00	13182.50	14212.00	15408.00
Thailand^{2}	35202.00	40232.50	44944.00	49428.00

Table 10. continued.

Country	1967-71	1972-75	1976-80	1981-85
Africa				
Burundi[1]	3324.40	3622.75	4055.20	4580.47
Cameroon[3]	6394.00	7292.50	8138.00	9576.00
Cent. African Rep.[1]	1662.00	1982.50	2220.00	2480.00
Ivory Coast[2*]	4942.00	6302.50	7634.00	9136.00
Ethiopia[1]	24042.00	26582.50	35404.00	41404.00
Gabon[3]	493.60	518.50	536.40	572.32
Gambia[1]	454.60	495.00	556.20	652.57
Ghana[1]	8447.80	9470.00	10877.80	12892.60
Kenya[1]	10876.00	12717.50	15016.00	18804.00
Liberia[2]	1310.00	1485.00	1726.00	2046.00
Madagascar[1]	6680.00	7380.00	8248.00	9454.00
Nigeria[3*]	53759.00	60434.75	70413.40	85315.24
Rwanda[1]	3582.00	4036.50	4587.00	5282.00
Sierra Leone[1]	2600.00	2937.50	3192.00	3474.00
Somalia[1]	2729.80	3047.50	3805.40	5299.20
Sudan[1]	13194.00	15210.00	17490.00	20380.00
Tanzania[1]	12908.60	14753.25	16889.20	19757.29
Togo[1]	1904.00	2147.50	2414.00	2800.00
Zaire[1]	21033.00	23613.00	26621.20	30847.31
Zambia[1]	4170.00	4794.25	5471.20	6381.63

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